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Inheritance and Yield with Particular Reference to Rust Resistance and Panicle Type in Oats

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UNIVERSITY FARM, ST. PAUL

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INHERITANCE AND YIELD WITH PARTICULAR REFERENCE TO RUST RESISTANCE AND PANICLE TYPE IN OATS

By R. J. Garber

INTRODUCTION

The accumulation of facts concerning inheritance has engaged the attention of a large number of biologists since the rediscovery in 1900 of Mendel's laws. Mendel's laws of inheritance and the genetic facts subsequently discovered are the working tools of the plant breeder. It is true that plants and animals were improved by breeding long before the era of Mendelism, but it was progress without a knowledge of the principles involved. At present the plant or animal breeder has at his disposal a set of facts which suggest the general plan of attacking a particular problem.

Next in order of importance to the fundamental laws of inheritance, is the discovery of the manner of inheritance of a particular character. One can not intelligently outline a project for improving plants or animals with regard to certain characters until something is known of the mode of inheritance of those characters. Extensive contributions have been made in this field as to both morphological and physiological characters.

The breeding of plants for disease resistance will always play an important rôle in the breeding of economic plants. Already much has been accomplished, both as to the discovery of the modes of inheritance of resistance to certain diseases and as to the actual production of disease resistant forms possessing economic value. Of the greatest importance to one who seeks to improve plants by breeding for disease resistance is the fact that this character obeys the same fundamental laws of inheritance as plant characters in general.

The investigation reported in this paper resulted from an attempt to combine resistance to stem rust, *Puccinia graminis avenae*, and high yield in oats. A preliminary survey revealed an oat strain which possessed striking resistance to stem rust but unfortunately had only mediocre yielding ability under conditions which were obtained at University Farm, St. Paul, Minnesota. This resistant strain was crossed reciprocally with two high-yielding susceptible strains. The progenies of these crosses were studied during a period of three years primarily for the purpose of ascertaining the manner of inheritance of resistance to stem rust in oats.

REVIEW OF LITERATURE

Bolley (1901, 1903, 1909), at the North Dakota Experiment Station, pointed out a method of producing flax resistant to wilt, *Fusarium lini.* Seed from disease resistant plants growing on soil known to be infested with the wilt-producing organism was saved and again planted on infested soil. By continuing this practice for a few years, flax resistant to wilt was isolated. Bolley's results have been corroborated at the Minnesota Experiment Station (Stakman, *et al,* 1919).

Tisdale (1916, 1917) has pointed out what an important rôle environment plays in determining susceptibility to flax wilt. High temperatures materially decrease resistance. As the result of a study of the F_1 and F_2 progenies of certain flax crosses the same author suggested that the inheritance of resistance to this disease could be explained by means of multiple factors.

An early attempt to combine disease resistance and high yield was made with the cowpea (Webber and Orton, 1902; Orton, 1902). The variety Iron[1], which is resistant to rootknot, *Heterodera radicicola;* and wilt, *Neocosmospora vasinfecta,* var. *tracheiphila,* was crossed at first with several sprawly unproductive forms and later with upright productive forms. From the later crosses the variety Monetta, which has disease resistance and high-yielding ability, was obtained. Brabham, a variety produced by a farmer, has the same parentage as Monetta, namely, Iron and Whippoorwill, and has consistently shown itself superior to Monetta. Orton (1911) has found that resistance to the above disease is inherited as a dominant character.

Conqueror, an edible variety of watermelon resistant to wilt, *Fusarium niveum,* is the result of a cross between a resistant, non-edible stock melon or "citron" and a susceptible, edible form (Orton, 1911).

In general, resistance to wilt, *Fusarium vasinfectum,* in cotton is inherited as a dominant character (Orton, 1911). Commercial cotton resistant to this disease has been produced by selection for resistance among plants growing on soil infested with the organism causing wilt.

By selecting under disease conditions, Bain and Essary (1906) were able to isolate red clover resistant to anthracnose, *Collectotrichum trifolii.*

Edgerton (1918) and Durst (1918) have been successful in isolating tomatoes resistant to wilt, *Fusarium lycopersici.* Edgerton grew the seedlings under disease conditions and only those showing resistance were transplanted to the field. The field was likewise known to be infested with the fusarium causing the disease. In a cross between two varieties of tomatoes, one resistant, the other susceptible to blossom-end rot, Stuckey (1916) found resistance an inherited character.

[1] Part of the following information was furnished in a letter from Dr. C. V. Piper to Dr. H. K. Hayes.

The F_1 as well as the F_2 generation was not attacked by blossom-end rot. No segregation occurred in the F_2 generation which was made up of 91 individuals coming from five F_1 plants.

Ikeno (1918) has reported that susceptibility to *Leptosphaeria cattanei* in rice is inherited as a dominant character.

At the Wisconsin Experiment Station, cabbage resistant to yellows, *Fusarium conglutinans* Wollenw., has been produced (Jones and Gilman, 1915) (Jones *et al,* 1920). These investigators emphasize the fact that environment influences very markedly the development of the disease. Resistance is relative, not absolute.

Barrus (1918) has made a careful survey of varieties of beans with respect to their relation to anthracnose, *Colletotrichum lindemuthianum.* Two strains of anthracnose were discovered. It was possible to place the varieties of beans into four groups as follows.

(ab) Varieties susceptible to both strain alpha and strain beta.

(aB) Varieties susceptible to strain alpha but resistant to strain beta.

(Ab) Varieties resistant to strain alpha but susceptible to strain beta.

(AB) Varieties showing some resistance to both strains.

Varieties, whose anthracnose reactions are known, have been crossed and the results reported (Burkholder, 1918; McRostie, 1919, 1921). Resistance to either the alpha or beta strain was found to be inherited as a dominant character dependent on a single factor difference for its expression.

McRostie (1921) has also reported the results of an investigation regarding the inheritance of resistance to bean mosaic and dry root rot caused by *Fusarium martii phaseoli* Burk. The F_1 showed a partial dominance of susceptibility to mosaic, and segregation in F_2 indicated a two-factor difference between resistance and susceptibility of the plants used as parents. In the case of dry root rot susceptibility proved dominant and the F_2 generation gave an approximation to a 9:7 ratio. Nearly all F_2 resistant plants bred true to resistance in F_3.

Resistance to bunt smut, *Tilletia tritici,* in wheat is clearly an inherited character as is shown by the work of Gaines (1918, 1920) at the Washington Experiment Station. In the cross between the varieties Florence and Turkey, forms were obtained in F_2 that showed a higher degree of resistance than the resistant parent. The results indicated that several factor differences were involved in the inheritance of this character.

At the Washington Agricultural Experiment Station (Waskabayashi, 1921) a study was made of the inheritance of resistance to covered smut, *Ustilago laevis avenae.* In a cross between resistant Red Rustproof oats, *Avena sterilis,* and susceptible Black Tartarian, *Avena*

orientalis, resistance to this disease was inherited as a dominant character. Three F_1 and 112 F_2 plants were grown. No smutted plants were found in the F_1 or F_2 generations and of 107 F_3 families only 12 produced smutted plants.

A rust, *Puccinia asparagi,* at times has been very destructive to asparagus in the eastern United States. Norton (1911-12, 1913) has shown that resistance to the fungus is an inherited character. The variety of asparagus known as Washington (Norton, 1919) is the result of crossed seed produced by highly resistant parents.

Webber, *et al,* (1912) succeeded in isolating strains of timothy resistant to rust, *Puccinia graminis.* The resistant strains were discovered by the plant-to-row method of selection. Eleven of the better sorts were tested at the Minnesota station and were found to be highly resistant to rust altho each strain produced some susceptible plants (Hayes and Stakman, 1919).

Extensive studies of rust resistance in wheat have been carried out. Biffen (1907, 1912, 1917) found susceptibility to stripe rust, *Puccinia glumarum,* dominant over resistance. The F_2 showed monohybrid segregation. In a similar study, Nilsson-Ehle (1911) found the F_1 generation susceptible in some cases, resistant in others, and intermediate in still others. The segregation obtained was explained by means of the multiple factor hypothesis. Three pure line selections of winter wheat have proved resistant to leaf rust under Kansas conditions (Melchers and Parker, 1920). Observations were made over a period of six years.

Results of a study of the inheritance of resistance to stem rust, *Puccinia graminis tritici,* have been reported by Hayes *et al* (1920). Resistant emmers and durums were crossed with Marquis, a susceptible bread wheat. The F_1 of the durum-Marquis cross was as susceptible as the Marquis parent whereas the F_1 of the emmer-Marquis cross was resistant altho not as resistant as the emmer parent. In both cases later generations showed segregation. Evidence of linkage between rust resistance and the durum and emmer spike characters respectively were obtained. In the above study a single rust form was used in making the artificial epidemic.

Waldron (1921), at the North Dakota station, has reported on the inheritance of resistance to stem rust based on a family derived from a cross between durum and common wheats. Segregation occurred and a linkage relation between durum characters and rust resistance was found. In this study no artificial rust epidemic was created.

The existence of a number of biological forms of stem rust differentiated only by their respective reactions to pure lines of wheat has been clearly demonstrated (Stakman *et al,* 1919). The parasitic reaction of each form was found to be constant.

A comparison of oat varieties with respect to their reaction to stem rust, *Puccinia graminis avenae* Erikss. and Henn., and crown rust, *Puccinia lolii avenae* McAlpine, has been made (Parker, 1918). Several varieties of *Avena sterilis* proved resistant to crown rust, while certain strains of *Avena sativa orientalis* proved resistant to stem rust. In crosses of Burt with Sixty Day (Parker, 1920), resistance to crown rust was found to be an inherited character. In F_2, resistant, susceptible, and various intermediate plants were obtained.

A comprehensive survey of oat varieties with respect to their reaction to both stem and crown rusts has been made at the Iowa Agricultural Experiment Station (Durrell and Parker, 1920). Strains of White Russian oats were found to possess a high degree of resistance to stem rust. The average percentage infection of crown rust among the varieties of *Avena sterilis* was less than the average obtained for the varieties of *Avena sativa*. A relation between time of planting and percentage of rust infection was noted. A slightly heavier infection of stem rust was obtained on the later planted oats, whereas the opposite relation was observed with respect to crown rust.

A preliminary note on the present investigation has been published (Garber, 1921).

HISTORY AND METHODS

During the course of a varietal survey of oats with respect to their reaction to stem rust, *Puccinia graminis avenae,* conducted at the Minnesota Agricultural Experiment Station, a strain belonging to the White Russian group of *Avena sativa orientalis* consistently proved to be highly resistant to this rust fungus. Unfortunately, the oat strain possessed only mediocre yielding ability. Because of their high-yielding ability under Minnesota conditions, the varieties Minota and Victory, both *Avena sativa*, were crossed with the rust resistant White Russian strain.

The pure-line Minota is a selection from an unnamed variety of commercial oats. It matures about the same season as Swedish Select. The branches of the panicle show a tendency to droop when ripe. The seed is white and the straw medium fine. Minota is susceptible to stem rust but has consistently shown itself a high yielder under Minnesota conditions.

Victory, the other high-yielding parent, is a pure-line production of the Svalof Agricultural Experiment Station, of Sweden. It possesses characteristics common to the Swedish Select group of *Avena sativa*. The panicle is open, rather short, with branches somewhat ascending. The seed is white and the culms medium coarse. Victory, like Minota,

has always shown a high degree of susceptibility to stem rust. In a normal season Victory matures from ten days to two weeks later than early oats such as Kherson and Sixty Day.

The White Russian pure-line strain used as the resistant parent has a side panicle and white seed and is late in maturing. The culms are medium fine and grow somewhat taller than those of Victory or Minota. Altho White Russian has not shown high-yielding ability at University Farm, it has always given evidence of a high degree of resistance to stem rust when this fungus was known to be present.

The susceptible parents and the resistant parent described above were reciprocally crossed in the plant breeding nursery at University Farm, St. Paul, during the summers of 1918 and 1919. Enough F_1 plants were matured in the greenhouse in the winter and early spring of 1918-19 to obtain a small F_2 generation the following summer. This generation and the parents were grown in the plant breeding nursery. They were planted considerably later than the rest of the oat nursery which proved to be a fortunate circumstance. The natural stem rust epidemic which occurred that year attacked particularly the oats later in maturing. When the bulk of the oat nursery had been harvested, the F_2 generation and the parents were still quite green. At intervals of a few days, beginning at heading time, the hybrid and parent plants were sprinkled with water and immediately after sprinkling, small bundles of heavily rusted straw were vigorously rubbed together over the plants. By this means a heavy rust infection was procured on almost all susceptible plants.

The F_3 generation produced by these F_2 plants together with other material used in this study was grown in the plant pathology nursery during the summer of 1920. In 1921, also, the plants studied were grown in the pathology nursery. The artificial rust epidemics created during the summers of 1920 and 1921 were made under the direction of the section of plant pathology.

The rust epidemic was induced by hand inoculation, by spraying, and by distributing throughout the nursery potted oat plants on which the rust fungus had developed previously in the greenhouse. Hand inoculation was practiced only relatively early in the process of bringing about epidemic conditions. By means of a suitable small spatula, uredospores were smeared on the under surface of moistened leaves of the susceptible parents at the region where most rapid leaf growth takes place. As soon as epidemic conditions were apparent, spraying only was practiced. A spray of a suspension of uredospores in water was applied in the evening several times a week until the desired degree of infection was obtained. The suspension was prepared by macerating recently collected, heavily rusted oat stems and leaves in water. Care was taken to apply the spray uniformly on all hybrid plants as well as on the parents.

In 1920, owing to the absence of stem rust on oats early in the growing season, it was necessary to procure uredospores outside of Minnesota. A bundle of oat straw carrying uredospores of *Puccinia graminis avenae* was obtained from Oklahoma. This material, together with some local stem rust which appeared later in the season, was used for the source of the epidemic in 1920. The rusts obtained from the two localities apparently produced the same parasitic reaction with the host plants. Owing to the somewhat adverse season for the development of the fungus and the fact that stem rust was not available early in the season, the epidemic this year was not so severe as desired, altho a moderately uniform infection was obtained.

In 1921 the source of the epidemic was stem rust obtained locally which had been carried through the previous winter on susceptible oat varieties growing in the greenhouse. By means of successive plantings and seedling inoculation it was not difficult to carry the rust in the uredospore stage through the winter. The work of producing an epidemic in the nursery was begun early in the season and proved highly successful. In 1921 an exceptionally severe epidemic of stem rust was obtained.

All the plants grown in connection with this study were planted in five-foot rows and spaced approximately two and one-half inches apart in the rows. The rows were one foot apart. In 1919 the parents were grown on both sides of the small plot containing the F_2 plants. In 1920 each parent grown in two five-foot rows appeared eight times distributed throughout the nursery. In addition to the F_2 and F_3 generations grown this year, 26 F_1 plants were produced and subjected to the rust epidemic. The entire nursery was surrounded with three rows of Victory oats. In 1921 the White Russian parent, again grown in two five-foot rows, appeared six times throughout the nursery. Two rows of each parent were grown at the beginning and at the end of the plot containing the F_2 generation. In the F_3 generation two five-foot rows of the susceptible parent were grown every 12 rows, i. e., Minota with the Minota-White Russian F_3 and Victory with the Victory-White Russian F_3, respectively. In addition a row of Victory was grown on each side of the alley between plot series and at a distance of about six inches from the ends of the five-foot rows. The entire nursery was again surrounded as in the previous year with three rows of Victory. The frequent appearance of the susceptible parents aided in producing a rust epidemic.

In analyzing the data presented in this paper, the method of least squares has been used. All computations involving decimals were carried to the fourth place beyond the decimal and the fourth digit dropped. In calculating the probable errors of Mendelian ratios, two methods were employed. When but two frequency classes were avail-

able, the ordinary formula for computing probable errors was used. If there were more than two frequency classes, the method suggested by Harris (1912) and based on a mathematical criterion evolved by Pearson (1900) was used. The values for "goodness of fit" (P) were taken from Elderton's (1901-02) table.

NATURE OF RESISTANCE TO STEM RUST IN OATS

In a recent issue of Science, Miss Allen (1921) ascribes resistance of Kanred wheat to stem rust, *Puccinia graminis tritici*, obtained from the Berkeley breeding plots, to size of stomatal openings. Measurements of the apertures of stomata on the leaves of Mindum and Kanred seedlings grown in the greenhouse were made. Mindum wheat, which is relatively susceptible to this particular biological form of rust, was found to have stomatal openings of about twice the width of the stomatal openings of Kanred. It is suggested that the cause of resistance in this case is solely morphological, i. e., the stomatal apertures of Kanred are small enough to prevent largely the parasitic fungus from entering the host.

A study somewhat similar to that of Miss Allen was made in the present investigation. Six and seven plants of the Victory and White Russian parents, respectively, together with a single plant of each of three different F_3 families breeding true for rust reaction and panicle type, were examined for size of stomata. The plants were pulled in the nursery about two weeks before harvest and the roots immediately immersed in water. In this condition they were taken to the laboratory and by means of a razor, strips of the epidermis were peeled from the under surface of the green leaves and mounted in distilled water. With a screw micrometer, measurements of the length of the major and minor axes through the guard cells were made. The stomata were measured immediately after the epidermal layer had been removed from the plant. The data for length and breadth of 25 stomata from each plant is presented in Tables I and II respectively.

TABLE I

FREQUENCY DISTRIBUTIONS SHOWING LENGTH OF STOMATA THROUGH THE GUARD CELLS ON THE UNDER SURFACE OF CERTAIN OAT LEAVES

Name	No. of plants	Frequency classes One increment = 0.23μ									Total	Mean	Diff. P. E.*
		155	165	175	185	195	205	215	225	235			
Victory	6	3	32	51	42	16	4	2			150	178.7±0.6	14.0
White Russian	7	1	15	27	32	30	30	16	15	9	175	195.5±1.0	
F_3 open, Re†	1				4	8	5	8			25	191.8±1.5	1.5
F_3 open, Su	1			1	1	6	8	7	2		25	195.0±1.6	
F_3 side, Re	1		2	7	6	5	3	6	1		25	185.8±2.2	0.8
F_3 side, Su	1		1	1	6	4	7	6			25	188.2±1.9	

*In this and subsequent tables, Diff. P. E. is written adjacent to the smaller quantity.
†Re = resistant; Su = susceptible.

The difference between the average lengths of stomata of Victory and White Russian is 14 times its probable error and the difference in breadth of stomata between the means of the same two varieties is 2.8 times its probable error. Apparently White Russian has somewhat longer but slightly narrower stomata than Victory.

The four F_3 plants revealed no significant differences in mean length of stomata between plants of the same panicle type but unlike rust reaction. The F_3, open-panicled, susceptible plant and the F_3, side-panicled, resistant plant showed respectively the longest and the shortest mean lengths of stomata; the difference being 9.2 ± 2.7 or approximately 2.1μ. With the exception of the side-panicled, susceptible plant, the F_3 individuals had about the same mean breadth of stomata. A difference 8 times the probable error was found between the means of width of stomata in the two side-panicled plants. The stomata of the resistant plant had a mean width of 13.3μ while that of the susceptible plant was 15.0μ. Owing to the small number of measurements made on the F_3 plants, the means may be considered as approximations only.

TABLE II

FREQUENCY DISTRIBUTIONS SHOWING BREADTH OF STOMATA THROUGH THE GUARD CELLS ON THE UNDER SURFACE OF CERTAIN OAT LEAVES

Name	No. of plants	Frequency classes One increment = 0.23μ											Total	Mean	Diff P. E.
		47	50	53	56	59	62	65	68	71	74	77			
Victory	6			12	21	29	30	33	15	8	2		150	58.8±0.3	
White Russian	7	1	8	24	60	45	24	8	1	3	1		175	57.7±0.2	2.8
F_3 open, Re	1				4	8	6	3	3	1			25	58.5±0.6	0.1
F_3 open, Su	1				4	7	5	7	1	1			25	58.6±0.5	
F_3 side, Re	1			4	1	4	9	6	1				25	57.8±0.6	8.0
F_3 side, Su	1					1	4	7	4	3	4	1	1	25	65.0±0.7

In addition to determining the length of the major and minor axes through the guard cells of stomata from plants growing in the nursery, measurements were also made of the width of stomatal openings in seedlings of Victory and White Russian. The seedlings were grown in six-inch pots in the greenhouse and examined about two weeks after planting. By placing the seedlings in a moist chamber under diffused sunlight, the stomata were induced to open fully. In this condition the seedlings were removed and immediately epidermal strips were taken from the under surface of the leaves and fixed in absolute alcohol. Epidermal layers from the leaves of several plants of each of the pure-line parents were examined. The measurement taken was the width of the stomatal opening at the widest point. The results obtained are presented in Table III.

TABLE III

FREQUENCY DISTRIBUTIONS SHOWING WIDTH OF STOMATAL OPENINGS WHEN FULLY OPEN. VICTORY AND WHITE RUSSIAN SEEDLINGS

Name	Frequency classes One increment = 0.23μ												Total	Mean	Diff P. E.
	17	20	23	26	29	32	35	38	41	44	47				
Victory	4	21	25	33	11	7							101	24.4±0.3	24.5
White Russian			1	1	21	26	21	19	11	1	1		102	34.2±0.3	

The stomatal openings of Victory have a mean width of 5.6μ whereas those of White Russian have a mean width of 7.9μ. The latter parent, which is resistant to stem rust, showed wider stomatal openings than the susceptible Victory. The difference is approximately 2.3μ, which is 24.5 times the probable error. If size of stomatal opening prevented the rust mycelium from penetrating the leaf tissue, width of opening would be the limiting factor.

From the data presented above it is apparent that resistance to stem rust in the oat plants examined can not be attributed to relative size of stomatal openings. Moreover the fact that numerous small uredinia develop on the resistant parent as well as the resistant progeny is *prima facie* evidence that the fungus gains admittance to the inner tissues of the host. It seems that the cause of resistance in this case is physiological rather than morphological in nature. This conclusion is in agreement with that of Jakushkina and Vavilov (1912) as a result of a study of size, number, and distribution of stomata in relation to resistance and susceptibility to rust in different varieties of oats.

Stakman (1914) has shown that resistance of wheat to stem rust, *Puccinia graminis tritici*, is due primarily to a physiological relationship between host and fungus.

In oats the surface of the stems, particularly near the nodes of susceptible plants heavily infected, becomes a mass of rust spores. On the other hand similar regions of resistant plants grown under the same conditions show the surface broken with many relatively minute uredinia. The amount of rust found on resistant plants as well as on susceptible plants varied considerably. Many of the resistant plants showed no uredinia whatever. By means of the size of the uredinia formed on the two categories of oat plants, resistant and susceptible, it was possible to make a clear-cut classification on the basis of rust reaction. Rust-infected susceptible plants gave rise to large oblong uredinia (the confluence of many uredinia) producing relatively long lesions in the stem, whereas resistant plants under the same conditions gave rise to minute uredinia varying in size from scarcely visible to the unaided eye to the size of an ordinary pin head. Figure 1 illustrates the difference between resistance and susceptibility to stem rust as the terms are used in the present paper.

Fig. 1. Types of Reaction to Stem Rust in Oats. At left, two culms of Victory, one of the susceptible parents; two culms of White Russian, the resistant parent. Note the difference in the character and number of uredinia. (Photo by George.)

INHERITANCE OF RUST REACTION AND PANICLE TYPE

The notes on rust reaction and panicle type of all the plants studied except the F_3 generation grown in 1920, were taken in the field immediately after the plants were pulled. The breeding nature of the F_3 generation grown in 1920 was determined while the plants were still standing and just before harvest. Little difficulty was experienced in classifying plants with respect to their rust reaction, but in regard to panicle type the phenotypes were not so clearly differentiated. In the F_3 generations, the families homozygous for open panicles (similar to the parents) were easily determined as they stood out in marked contrast to the other F_3 families.

The reliability of the F_2 classification with respect to the two characters, susceptibility to stem rust and the side panicle type, for all the cultures carried through the F_3 generation, is shown in Tables IV and V, respectively. The number of F_2 plants recorded as side-panicled and the nature of their progeny in F_3 are given. Similar data for rust susceptibility are presented.

In the Victory-White Russian[2] cross, out of a total of 38 F_2 plants classified as susceptible, 35 proved homozygous susceptible, 2 segregated, and 1 bred true for resistance in F_3. The total number of F_3 families homozygous for susceptibility was 37. Of 58 F_2 plants recorded as susceptible in the Minota-White Russian cross, 51 bred true to susceptibility, 5 segregated and 2 were resistant in F_3.

TABLE IV

RELIABILITY OF CLASSIFICATION OF F_2 PLANTS FOR SUSCEPTIBILITY TO RUST ON THE BASIS OF F_3 BREEDING NATURE

Name	No. of F_2 plants classed as susceptible	F_3 families		
		Breeding true for susceptibility	Segregating for rust	Breeding true for resistance
Victory-White Russian	38	35	2	1
Minota-White Russian	58	51	5	2

A total of 59 F_3 families proved homozygous for susceptibility. Altho there were several F_2 plants wrongly classified in both crosses, the total number of F_2 plants noted as susceptible in F_2 and the total number of F_3 families which proved homozygous for susceptibility closely correspond. Considering both crosses these totals are the same, 96 susceptible F_2 plants and 96 F_3 families homozygous for susceptibility.

With respect to panicle type, greater discrepancies occurred between the F_2 classification and the actual genotypic condition as revealed by the F_3 progeny. In the Victory-White Russian cross 26 F_2 plants were

[2] Where the symbol "—" is used, word order has no significance as to parentage, i. e., male or female. Such a compound word may indicate a particular cross, the reciprocal, or both.

noted as having side panicles but only 17 proved homozygous and 9 segregated in F_3. In all, 27 F_2 plants bred true in F_3 for the side panicle character. In the Minota-White Russian cross, of 29 F_2 plants recorded as having side panicles, 24 bred true and 5 segregated in F_3. However, the F_3 generation of this cross revealed 39 families homozygous for the side-panicled type. The total number of F_2 plants in both crosses noted as side-panicled forms was 55, whereas the number of F_3 families breeding true for side panicles was 66.

TABLE V

RELIABILITY OF CLASSIFICATION OF F_2 PLANTS FOR PANICLE TYPE ON THE BASIS OF F_3 BREEDING NATURE

Name	No. of F_2 plants classed as side panicle	F_3 families	
		Breeding true for side panicle	Segregating for panicle character
Victory-White Russian	26	17	9
Minota-White Russian	29	24	5

THE PARENTS AND THE F_1 GENERATION

During the three years that this investigation was in progress the approximate numbers of parental plants grown and studied with respect to their rust reaction and panicle type were as follows: 500 White Russian, 1000 Victory and 1000 Minota. The Victory and Minota plants without a single exception had open panicles (see Fig. 2) and showed large oblong uredinia of stem rust. On the other hand a careful examination of the 500 side-panicled plants of White Russian revealed none, few, or many minute uredinia.

All the F_1 plants except 26, were grown in the greenhouse and were not infected with stem rust. In 1920, 26 F_1 plants made up as follows: 2 White Russian × Victory[2], 5 Minota × White Russian, and 19 White Russian × Minota, were grown in the rust nursery and subjected to the same stem rust epidemic as the F_2, F_3, and parental plants. These F_1 plants showed the rust reaction characteristic of the White Russian parent, namely, a high degree of resistance. A few small uredinia were found on some of the F_1 plants. The evidence obtained from the F_1 generation shows that resistance to stem rust in the above crosses is inherited as a dominant character. With respect to panicle type, the F_1 plants were open, altho not so open as the open-panicled parents.

[2] The female parent is written first where the symbol x is used.

Fig. 2. Panicle Types of the Oats Used as Parents. Left to right, Minota, White Russian and Victory

THE F_2 GENERATIONS GROWN IN 1920 AND 1921

In Table VI is given a record of all F_2 plants grown in 1920 except those which were propagated in F_3. The data on each F_2 family were kept separate and later combined, as all the families showed they were crosses and gave similar results. The segregation with respect to rust reaction in the White Russian × Victory and reciprocal crosses is clearly that of a monohybrid showing complete dominance. Among the open-panicled plants there were 452 resistant and 141 susceptible, while among the side-panicled plants there were 115 resistant and 35 susceptible; the quotients of the deviations from the theoretical ratios divided by the probable errors being 1.0 and 0.7 respectively. In other words, deviations as great as these would be expected in about half the cases. In the Minota × White Russian cross, theory and observation do not agree so well. Among the open-panicled plants there were 466 resistant and 115 susceptible individuals, and among the side-panicled plants 69 resistant and 15 susceptible. The deviation with respect to segregation for rust in the open-panicled types is 4.3 times the probable error and in the side-panicled types 2.2 times the probable error. The Minota-White Russian cross matured on the average about a week earlier than the Victory-White Russian cross. It is probable that some of the F_2 plants of the former cross escaped infection in 1920 owing to the lateness of procuring rust epidemic conditions in the nursery.

TABLE VI

SEGREGATION WITH RESPECT TO RUST REACTION AND PANICLE TYPE IN THE F_2 GENERATION OF CERTAIN OAT CROSSES GROWN IN 1920

Name	Panicle type	Resistant plants	Susceptible plants	Total
White Russian x Victory	open	255	76	331
White Russian x Victory	side	70	21	91
Victory x White Russian	open	197	65	262
Victory x White Russian	side	45	14	59
Minota x White Russian	open	466	115	581
Minota x White Russian	side	69	15	84

The inheritance of panicle type can not be ascertained from the F_2 generation. Altho all plants were classified with respect to their panicles as open or side, it was evident that many plants showed more nearly an intermediate condition. In this investigation the F_2 intermediate panicle types were classified as open. In the crosses, White Russian × Victory and reciprocal, there were 593 and 150 F_2 plants classified as open and side, respectively, whereas in the Minota × White Russian cross 581 plants were classed as open and 84 as side. In the first case the deviation from a monohybrid ratio is 4.5 times the probable error and in the second 10.9 times the probable error. Assuming a single factor difference for panicle type in the

parents, the divergencies of the actual from the theoretical ratios in the F_2 of both crosses is too great to be attributed to the errors of random sampling. Fewer side-panicled plants were classified as such than would be expected on the basis of monohybrid segregation.

Nilsson-Ehle (1908) attributed the difference between open-panicled and side-panicled varieties of oats to two main factors. In the absence of both factors forms with side panicles are produced, whereas if one or both factors are present, forms with open panicles result.

In 1921 a severe epidemic of stem rust was obtained in the nursery. The data on all the F_2 plants grown that year, except those which were propagated in F_3, are shown in Table VII. In general, the segregation with respect to rust reaction corroborates that observed in 1920. The only group of plants showing a considerable deviation from expectation is the side-panicled types of the White Russian-Victory cross. In this group there were 53 resistant and 32 susceptible plants. Here the deviation is 4 times the probable error but only a relatively small number of plants is involved. It is interesting to note that altho the resistant parent has a side panicle, the number of susceptible plants with side panicles in the F_2 of the White Russian-Victory cross is in excess of expectation on a monohybrid basis. In F_2 the ratio of resistant to susceptible plants in the open-panicled group of the White Russian-Victory cross is 327:103, in the open-panicled group of the Minota-White Russian cross 505:147, and in the side-panicled group of the Minota-White Russian cross 72:20. The deviations from the theoretical ratios are respectively 0.7, 2.1, and 1.1 times the probable errors. Divergencies as great as these may reasonably be expected owing to the errors of random sampling.

TABLE VII

SEGREGATION WITH RESPECT TO RUST REACTION AND PANICLE TYPE IN THE F_2 GENERATION OF CERTAIN OAT CROSSES GROWN IN 1921

Name	Panicle type	Resistant plants	Susceptible plants	Total
White Russian x Victory	open	327	103	430
White Russian x Victory	side	53	32	85
Minota x White Russian	open	232	64	296
Minota x White Russian	side	48	11	59
White Russian x Minota	open	273	83	356
White Russian x Minota	side	24	9	33

The data with regard to segregation for panicle type in F_2 (Table VII) are similar to those obtained the previous year (Table VI). There is a smaller number of plants with side panicles than would be expected on the basis of monohybrid segregation. In the cross, White Russian × Victory, 430 F_2 plants were classed as open and 85 as side, whereas in the F_2 generation of the crosses, Minota × White Russian and reciprocal, 652 plants were classed as open and 92 as side. The deviations of these two ratios from a 3:1 ratio are 6.6 and 11.8.

respectively, times their probable errors. The deviations of actual from calculated ratios are significant and can not be explained on the basis of chance.

THE F_3 GENERATIONS GROWN IN 1920 AND 1921

The genotypes with regard to rust reaction and panicle type of all the F_2 plants grown in 1919 and of 200 F_2 plants grown in 1920 were determined in 1920 and 1921, respectively, by the F_3 breeding test. A few F_3 families, grown in 1920, were discarded because they contained too few plants.

In the appendix Tables XXIII to XXV, inclusive, is contained the record of the F_3 Victory-White Russian cross and in Tables XXVI to XXIX, inclusive, the record of the F_3 Minota-White Russian cross. The number of plants and their rust reaction are shown for each F_3 family. With respect to panicle type, the F_3 families are classified as homozygous open, homozygous side, or segregating. An examination of the tables shows that F_3 families homozygous for both open panicle and resistance to rust, F_3 families homozygous for both side panicle and susceptibility to rust, and homozygous F_3 families similar to the parental forms in rust reaction and panicle type were easily obtained.

A summary of the analysis of inheritance of rust reaction and panicle type based on the segregation in F_2 as revealed by the F_3 breeding test, is presented in Table VIII (see appendix Table XXX). The F_2 plants are grouped on the basis of rust reaction into three classes, homozygous resistant, heterozygous resistant, and homozygous susceptible. Each of these groups is further classified on the basis of panicle type into three categories, open panicles, segregating, i. e., producing, both open and side panicles in F_3, and side panicles.

The Victory-White Russian cross produced 38 homozygous resistant, 65 heterozygous resistant, and 37 homozygous susceptible plants in the F_2 generation. Homozygous and heterozygous resistant plants have the same phenotype and can be distinguished only by their respective progenies. The above ratio is in close agreement with that expected on the basis of a single factor difference between resistance and susceptibility. The value of X^2 ($X^2 = 0.728$) is less than one, hence, the probability (P) is relatively great that the deviation is owing to errors of random sampling. In the Minota-White Russian cross 68 homozygous resistant, 110 heterozygous resistant, and 59 homozygous susceptible F_2 plants were produced. Closeness of fit (P) to the theoretical 1:2:1 ratio is 0.3910. In other words, a divergency as great as this would be expected in about two cases out of five solely from the errors of random sampling. Of the 377 F_2 plants from both crosses tested in F_3, about one fourth bred true to resistant, one half again segregated in the ratio of three resistant plants to one

susceptible plant, and one fourth bred true to susceptibility. (See Fig. 3.)

In the Victory-White Russian cross, the F_3 families showed that segregation of panicle types in F_2 was approximately in accordance with monohybrid expectation. Of 140 F_3 families, 33 and 27 were

TABLE VIII

SUMMARY SHOWING SEGREGATION OF F_2 PLANTS WITH RESPECT TO RUST REACTION AND PANICLE TYPE AS REVEALED BY THEIR F_3 PROGENIES

Name	Panicle type	Rust reaction			Total
		No. of F_3 families			
		Re.*	Seg.	Su.	
Victory-White Russian	Homo open	7	14	12	33
Victory-White Russian	Segregating	24	40	16	80
Victory-White Russian	Homo side	7	11	9	27
Total		38	65	37	
Minota-White Russian	Homo open	23	26	16	65
Minota-White Russian	Segregating	35	65	33	133
Minota-White Russian	Homo side	10	19	10	39
Total		68	110	59	

*Re = resistant; Seg = segregating; Su = susceptible.

homozygous open and side, respectively, while the remaining 80 families again segregated for panicle type. The probability (P= 0.1905 is about one in five that the deviation of this ratio from the theoretical 1:2:1 is owing to chance. In the Minota-White Russian cross, theory and observation do not agree. There is only about one chance in 100 that a deviation (P= 0.0100) as great as was obtained is because of random sampling. Sixty-five F_3 families were homozygous open, 133 segregated for panicle type, and 39 were homozygous side. If the segregating families are grouped with the side-panicled families, the ratio becomes 65 open to 172 non-open F_3 progenies. In this case the deviation from a 1:3 ratio divided by the probable error is 1.3; hence, the deviation is of little significance. The inheritance of panicle type in both these crosses seems to be controlled by one main factor difference. More evidence is needed to determine whether or not there are supplementary factors involved (see Figs. 4 and 5).

A summary of all the data on rust reaction in the F_3 families segregating for this character is shown in Table IX. The relative numbers of resistant and susceptible plants in each family were determined. An examination of the column containing the quotients of the deviations divided by their respective probable errors shows that theory and observation, with two exceptions, agree very well. In cultures 2-2-1, etc., the deviation is 5.8 times the probable error and therefore significant. If families 2-2-1, 2-2-11, and 2-2-42, which produced more susceptible than resistant plants are eliminated from cultures 2-2-1, etc., the ratio of resistant to susceptible plants becomes 662 to 227 respectively. In this instance Dev. P.E. is 4.75 8.708 0.5.

Fig. 3. Oat Culms of Victory, White Russian, and Two F_3 Families of a Cross Between Them Homozygous for Rust Reacton
Left to right, White Russian, susceptible F_3, resistant F_3, and Victory

TABLE IX

SUMMARY SHOWING SEGREGATION WITH RESPECT TO RUST REACTION IN ALL THE SEGREGATING F_3 FAMILIES

Name	Culture number	Year grown	No. of plants: Resistant	No. of plants: Susceptible	No. of plants expected (3:1): Resistant	No. of plants expected (3:1): Susceptible	Dev. P. E.
White Russian x Victory..	2-13-1, etc.	1920	500	177	507.75	169.25	1.0
White Russian x Victory..	2-2-1, etc.	1921	691	301	744.00	248.00	5.8
Victory x White Russian..	3-1-1, etc.	1921	567	203	577.50	192.50	1.3
Total.....	.....	.....	1758	681	1829.25	609.75	4.9
Minota x White Russian...	4-7-1, etc.	1920	953	237	892.50	297.50	6.0
Minota x White Russian...	4-8-1, etc.	1920	1026	357	1037.25	345.75	1.0
Minota x White Russian...	4-9-1, etc.	1920	823	259	811.50	270.50	1.2
Minota x White Russian...	4-4-1, etc.	1921	1404	436	1380.00	460.00	1.9
Total.....	.....	.....	4206	1289	4121.25	1373.75	3.9
Total for both crosses....	.....	.....	5964	1970	5950.50	1983.50	0.5

In cultures 4-7-1, etc., the divergence from expectation is six times the probable error. It is likely that a number of plants in these families were recorded as resistant because of their escape from rust infection. The rust epidemic in 1920, as has been pointed out, was somewhat light. Considering the total of all the plants in both crosses grown in 1920 and 1921, there were 5964 resistant and 1970 susceptible F_3 plants in the cultures segregating for rust reaction. In this case Dev./P.E. is 0.5. Resistance to stem rust in the above crosses is inherited as a dominant character showing monohybrid segregation among the progeny from individuals heterozygous for rust reaction.

RELATION BETWEEN PANICLE TYPE AND RUST REACTION

If the factor difference for rust reaction and panicle type in the above crosses were closely linked in inheritance, it would be necessary to produce a comparatively large number of F_2 plants to obtain open-panicled, rust-resistant individuals. Such was not the case, as an examination of Table VIII shows. Of 38 homozygous resistant F_2 plants in the Victory-White Russian cross, 7 bred true to open panicles and 7 to side panicles in the next generation. The 37 homozygous susceptible F_2 plants produced 12 and 9 F_3 families homozygous for open and side panicles respectively, and 16 F_3 families which segregated for panicle type. In the Minota-White Russian cross, the homozygous resistant F_2 plants gave 23, 35, and 10 homozygous open, segregating, and homozygous side F_3 families respectively. In the same cross the homozygous susceptible F_2 plants produced 16, 33, and 10 F_3 families breeding true for open panicles, segregating for panicle type and breeding true for side panicles respectively (see Figs. 4 and 5).

In the discussion of Tables VI and VII it was pointed out that the F_2 plants classified as side-paniculed forms with one exception showed monohybrid segregation with respect to rust reaction. The one excep-

tion, White Russian × Victory F_2 grown in 1921, produced more side-panicled, susceptible plants than would be expected on the basis of independent segregation. The same general relation was observed between open-panicled F_2 plants and their reaction to rust altho here again one exception appeared. More open-panicled, Minota × White Russian F_2 plants grown in 1920, were recorded as resistant to rust than were expected on the basis that rust reaction and panicle type were independently inherited. In both exceptions, however, the combination of the particular rust reaction and panicle type is opposite to the combination of these characters found in the parents, namely, side panicles with resistance and open panicles with susceptibility.

Part of the data collected in connection with a study of the relation of yield to rust reaction and to panicle type in the F_3 families grown in 1921 is of interest here. The plants in each F_3 family segregating for both rust reaction and panicle type were classified as open-panicled resistant, open-panicled susceptible, side-panicled resistant, and side-panicled susceptible. The data for the Minota-White Russian cross are presented in Table X. On the assumption that rust reaction and panicle type are independently inherited, one would expect a 9:3:3:1 ratio. The ratio for the total number of plants was 516 open-panicled resistant : 162 open-panicled susceptible : 166 side-panicled resistant : 61 side-panicled susceptible. The goodness of fit in this experiment is very close, the value of X_2 being less than one ($X_2 = 0.871$).

TABLE X

SEGREGATION WITH RESPECT TO RUST REACTION AND PANICLE TYPE IN CERTAIN F_3 FAMILIES OF MINOTA × WHITE RUSSIAN, GROWN IN 1921

Culture number	No. of Plants			
	Open Panicle		Side Panicle	
	Re	Su	Re	Su
4–4– ?	16	6	9	4
4–4–10	20	7	8	4
4–4–13	15	10	9	2
4–4–14	15	9	9	4
4–4–15	26	10	7	2
4–4–22	17	7	9	3
4–4–29	23	9	8	3
4–4–30	23	9	5	1
4–4–34	24	7	9	3
4–4–36	23	8	6	1
4–4–39	26	5	11	1
4–4–41	28	5	9	1
4–4–48	23	3	4	4
4–4–57	22	12	6	4
4–4–68	17	4	6	3
4–4–70	23	9	6	3
4–4–71	29	4	6	2
4–4–74	20	6	10	2
4–4–77	26	8	5	2
4–4–88	26	5	9	3
4–4–91	18	6	5	5
4–4–96	30	6	2	3
4–4–97	26	7	8	1
Total.....	516	162	166	61
Expectation (9:3:3:1)	509.063	169.688	169.688	56.563

$x^2 = 0.871$. P = close fit.

Fig. 4. Representative Panicles Obtained in Two F_3 Families Homozygous for Rust Resistance and Panicle Type in the Cross White Russian x Victory
Left to right, open panicle and side panicle

Fig. 5. Representative Panicles Obtained in Two F_3 Families Homozygous for Panicle Type in the Cross Minota x White Russian. Left to right, open panicle of susceptible family and side panicle of family segregating for rust.

Similar data for the White Russian-Victory cross are shown in Table XI. It will be noted that four F_3 families segregating for both rust reaction and panicle have been eliminated from this table. These families were arbitrarily omitted because they showed more susceptible than resistant plants. The total number of plants were classified as follows: 657, 187, 156, and 82 open-resistant, open-susceptible, side-resistant, and side-susceptible respectively. In this case the deviation from the theoretical 9:3:3:1 is so great that the probability of this divergency being due solely to the errors of random sampling is very remote. On the basis of chance such a deviation ($P = 0.0003$) would be expected to occur in only about three out of 10,000 cases. Considering the open-panicled group and the side-panicled group separately, it is of interest to note that on the basis of independent segregation the resistant plants are in excess in the former and the susceptible plants in the latter group. Again the combination of rust reaction and panicle type are opposite to that found in the parents. In an F_3 generation such a relation might arise because of cross-overs between linked

TABLE XI

SEGREGATION WITH RESPECT TO RUST REACTION AND PANICLE TYPE IN CERTAIN F_3 FAMILIES OF WHITE RUSSIAN X VICTORY AND THE RECIPROCAL, GROWN IN 1921

Culture number*	No. of plants			
	Open panicle		Side panicle	
	Re	Su	Re	Su
2-2-2	22	4	5	1
2-2-3	26	6	4	3
2-2-5	25	7	6	3
2-2-11	25	5	8	2
2-2-19	22	9	2	4
2-2-21	22	7	5	4
2-2-22	23	7	5	4
2-2-23	27	6	4	2
2-2-31	20	11	2	4
2-2-36	20	6	6	3
2-2-38	19	6	10	2
2-2-39	21	5	3	4
2-2-41	18	5	5	2
2-2-44	15	9	2	2
2-2-46	19	6	10	0
2-2-47	21	5	4	1
2-2-49	17	6	9	4
3-1-11	19	5	9	3
3-1-13	23	7	5	5
3-1-14	25	6	4	2
3-1-18	16	3	5	3
3-1-22	27	5	6	2
3-1-27	19	5	2	2
3-1-28	16	10	3	4
3-1-31	22	6	4	3
3-1-38	30	3	4	3
3-1-40	21	8	3	3
3-1-41	19	6	6	1
3-1-43	22	7	5	1
3-1-44	24	4	6	2
3-1-48	12	2	4	3
Total	657	187	156	82
Expectation (9:3:3:1)	608.625	202.875	202.875	67.625

P = 0.0003

*Families 2-2-1, 2-2-14, 2-2-42, and 3-1-3 omitted.

factors in the F_1 plants. Such an explanation for the above instance is untenable, particularly when all the evidence is considered. It is more probable that some of the F_2 plants classed as side-susceptible should have been classed with the open-susceptible group. Then, too, the number of plants classed as side-panicled is relatively small.

In view of the data presented, the two characters, rust reaction and panicle type, are not closely linked in inheritance. The factor difference controlling reaction to stem rust and the main factor difference controlling panicle type are either located in different chromosome pairs or, if in the same chromosome pair, the factors cross over frequently.

INHERITANCE OF POLLEN ABORTION

The Victory, Minota, and White Russian parents, together with representatives of the F_1, F_2, and F_3 generations grown in the nursery in 1920, were examined for aborted pollen. Florets in which the anthers were about ready to dehisce, were collected in the field and taken to the laboratory. Here the anthers were placed on slides and allowed to dehisce. This usually occurred a few moments after their removal from the florets. When the anthers proved too immature, a new sample was obtained. The pollen was mounted in an aqueous solution of acid fuchsin and lactic acid. Aborted pollen is not stained with this solution.

The percentage of aborted pollen on each slide was determined by making from five to fifteen counts of random samples each consisting of 100 pollen grains. The larger number of counts was made on the slides showing the greater percentages of aborted pollen. Each slide except those of the F_3 individuals contained pollen from a single plant. A preliminary examination revealed comparatively little variability of percentage aborted pollen in different anthers from the same plant. In view of this, but one or two anthers were used to constitute the pollen sample of a single plant.

Frequency distributions of the percentage aborted pollen in parental, F_1, and F_2 plants are shown in Table XII. The 10 plants of each White Russian and Minota showed an average of about one per cent sterile pollen whereas the 29 Victory plants showed an average of 12.4 per cent. In the 11 White Russian-Minota F_1 plants less aborted pollen was found than in the parents. A similar condition was observed in 42 F_2 plants of the same cross. In the White Russian-Victory cross only one F_1 plant was examined and it revealed 3.5 per cent aborted pollen. The range of the percentage of unstained pollen grains in the F_2 generation of this cross was from less than one to 14.5 per cent whereas the range in the Victory parent was from 8.5 to 18.5 per cent.

TABLE XII

FREQUENCY DISTRIBUTIONS OF PERCENTAGE ABORTED POLLEN IN PARENTS AND PROGENIES OF CERTAIN OAT CROSSES, EACH DETERMINATION MADE FROM A SINGLE PLANT

Name	Culture number	Frequency classes. Percentages of aborted pollen																			Total number of plants	Mean	S. D.	C. V.
		0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5				
White Russian, P_1		6	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	0.9	..	..
Minota, P_1		7	2	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	1.0	..	..
Victory, P_1		..	..	..	..	..	..	..	..	1	1	7	5	3	1	..	5	1	1	1	29	12.4±0.3	2.7±0.2	21.8±1.9
White Russian x Minota, F_1		10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	0.5	..	..
Minota x White Russian, F_1		1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	0.5	..	..
White Russian x Victory, F_1		..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	3.5	..	..
Minota x White Russian, F_2		39	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	42	0.6	..	..
White Russian x Victory, F_2		8	40	24	20	12	11	4	..	1	3	1	..	..	..	1	..	..	..	..	125	3.2±0.1	2.3±0.1	71.9±3.1
	2-2-1 to 2-2-125																							
Victory x White Russian, F_2	3-1-1 to 3-1-125	17	41	27	18	8	9	2	2	..	..	1	..	..	..	..	..	..	..	..	125	2.6±0.1	1.8±0.1	69.2±3.0

Of the 250 F_2 plants examined, only 7 showed percentage of aborted pollen within the range shown by the Victory parent. The mean percentage of sterile pollen in the Victory parent is approximately four times the mean of the F_2 generation. The absolute variability as measured by the standard deviations does not show a very great difference between the two groups of plants but the relative variability shows considerable difference. The F_2 generation has a coefficient of variability about three times that of the Victory parent. The segregation observed in the F_2 generation indicated that aborted pollen as found in the Victory parent was inherited as a recessive character involving at least two factors. More evidence is needed to establish with certainty the mode of inheritance of this character.

In order to determine if high percentages of aborted pollen were closely associated with panicle type, 7 F_3 families homozygous for open panicles and 7 F_3 families homozygous for side panicles were examined. An average of 20 counts of 100 pollen grains each was made on composite samples of pollen taken from different plants of the same culture (F_3 family). The number of plants from which the composite sample of pollen was collected, the panicle type, and the average percentage of aborted pollen for each F_3 family are shown in Table XIII. The open-panicled F_3 families exhibit a wider range of percentage sterile pollen than the side-panicled F_3 families, but the means of the average percentages are approximately the same for the open- and side-panicled forms. The mean for the open type is 3.7 and for the side type 3.8 per cent aborted pollen. In this connection it is of interest to point out that of the seven F_2 plants showing percentages of aborted pollen within the range exhibited by the Victory parents, six were classed as open-panicled and one as side-panicled. No evidence of a close association in inheritance between panicle type and pollen abortion was found. (See Fig. 6.)

TABLE XIII

AVERAGE PERCENTAGE OF ABORTED POLLEN IN DIFFERENT F_3 FAMILIES HOMOZYGOUS FOR PANICLE TYPE IN THE CROSS WHITE RUSSIAN X VICTORY. EACH DETERMINATION MADE FROM APPROXIMATELY 20 COUNTS OF 100 POLLEN GRAINS EACH

Culture number	No. of plants	Average percentage of aborted pollen	
		Panicle type	
		Open	Side
2-13- 2	15	...	3.7
2-13- 7	15	1.6	...
2-13-12	15	...	5.1
2-13-16	15	...	2.5
2-13-19	15	3.0	...
2-13-20	15	...	3.4
2-13-26	13	...	4.7
2-13-27	6	7.4	...
2-13-31	15	...	5.5
2-13-32	15	0.7	...
2-13-33	6	1.3	...
2-13-34	6	6.1	...
2-13-37	15	5.6	...
2-13-39	15	...	2.0
Average	...	3.7	3.8

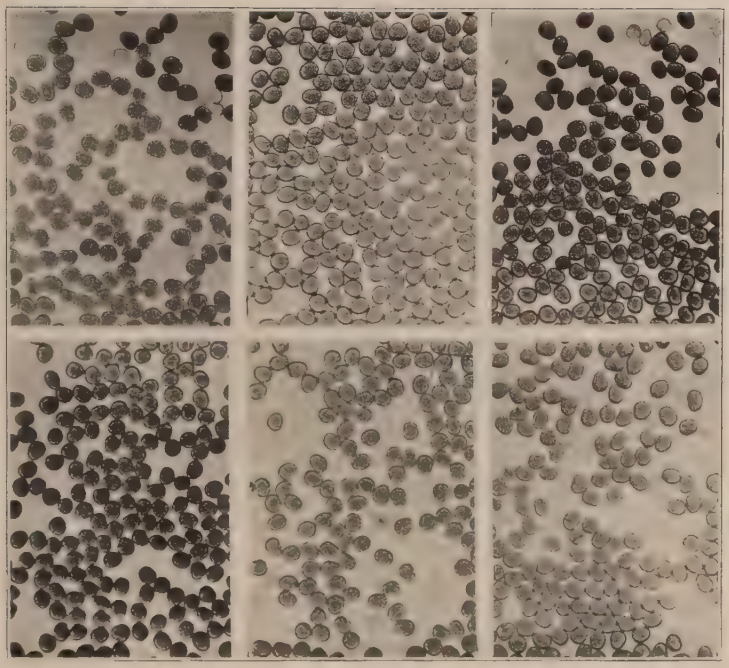

Fig 6. Photomicrographs Showing Aborted Pollen in Oats. From left to right, upper row, Victory parent, White Russian parent, and F_1 cross between them; lower row, three different F_2 plants of the same cross. Aborted pollen appears clear in the plate.

YIELD IN RELATION TO RUST AND PANICLE TYPE

It is commonly conceded that stem rust decreases yield. Estimates have been made from time to time of the damage caused by this fungus but little experimental data have been collected. Bluestem wheat, at the North Dakota Experiment Station (Walster, 1921) gave an annual average yield of 7.1 bushels per acre during five rust years and 26.7 bushels per acre during five non-rust years. During the ten-year period from 1911 to 1920, inclusive, stem rust of wheat was epidemic in Minnesota in 1916, 1919 and 1920[4]. The average yield for these years was 8.6 bushels while for the seven remaining years the average yield was 15.4 bushels.

In the variety tests conducted at University Farm, the open-panicled oats have generally yielded more than the side-panicled forms. The varieties Victory and Minota, which have open panicles, have consistently showed yielding ability superior to that of the White Russian variety, a side-panicled form.

The material grown in 1921 in connection with the study of the inheritance of rust reaction and panicle type, was particularly suitable for studying the relation of these characters to yield. The parents and all the F_3 families except one were grown in plots consisting of two five-foot rows. Because of the small quantity of seed, one F_3 family was grown in a single five-foot row. The planting plan of that part of the nursery which contained the F_3 families is shown in Tables XXXV and XXXVI in the appendix. Some of the F_3 families were eliminated from the yield study, because of the relatively large number of injured plants. In the other F_3 families, the F_2 generation, and the parents, no plant which showed the loss of a panicle was harvested for yield.

The plants at the end of each row did not show noticeable border effect, owing undoubtedly to the fact that a drilled row of Victory was grown on each side of the alleys between plot series. The drilled rows of Victory were grown at a distance of about six inches from the ends of the plots. Moreover, the number of plants involved in this study is such that influence of border would not materially change the relative difference between average yields of the different classes of plants, i. e., between open resistant and open susceptible, etc. In view of these considerations, plants growing at the ends of the plots were not omitted from the yield study.

All the F_2 generations and all but three of the F_3 families homozygous for rust resistance were harvested as individual plants and their yields determined.

[4] From summaries on yields furnished by the courtesy of Professor Andrew Boss.

The other F_3 families and the parents were harvested and bulk yields of each plot ascertained. The plants of each plot showing segregation for either panicle type or rust reaction or for both characters were classified as open resistant, open susceptible, side resistant, and side susceptible. After noting the number of plants, the panicles of each class of plants were removed and placed in separate muslin bags. The parents and the F_3 families homozygous for rust reaction and panicle type, except those of which individual plant yields were determined, were harvested in a similar way. In this case there was of course but one class of plants in each plot. When dry both the individual plants and the bulk samples were threshed in an individual plant thresher.

INDIVIDUAL PLANT YIELDS

The relation of rust reaction and panicle type to yield in the F_2 generation is shown in Tables XIV and XV. The frequency distribution, number of plants, and mean yields are shown for each class of plants in each of the two different crosses. The significance of the differences between mean yields based on rust reaction may be ascertained from the column at the extreme right of each table. The quotient of the difference divided by its probable error appears adjacent to the smaller quantity.

In the open-panicled forms (Table XIV) of the Victory-White Russian cross the resistant plants yielded an average of 0.81 grams more seed than the susceptible plants. This difference is more than ten times its probable error and is about 37 per cent of the mean yield of the resistant plants. In the open-panicled plants of the Minota-White Russian cross, the average yield of the susceptible plants is 0.23 grams less than of the resistant plants. The difference is about 12 per cent of the average yield of the resistant plants and is 2.9 times the probable error.

TABLE XIV

FREQUENCY DISTRIBUTIONS OF YIELD IN RELATION TO RUST REACTION IN THE OPEN-PANICLED TYPE OF THE F_2 GENERATION OF CERTAIN OAT CROSSES, GROWN IN 1921

Name	Rust class	Yield classes in grams													Total	Mean	Diff. P. E.
		0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75			
[illegible]	Re	23	41	42	41	58	43	35	18	11	8	2	..	2	1	325	2.17±0.05	.....
[illegible]	Su	11	28	30	11	..	..	1	1	1						102	1.86±0.06	10.1
[illegible]	Re	71	67	78	69	55	55	47	30	15	9	5	2	..	1	504	1.94±0.04	.....
[illegible]	Su	20	26	23	27	16	12	6	6	3	1	3	..	..	..	143	1.71±0.07	2.9

TABLE XV

FREQUENCY DISTRIBUTIONS OF YIELD IN RELATION TO RUST REACTION IN THE SIDE-PANICLED TYPE OF THE F_2 GENERATION OF CERTAIN OAT CROSSES, GROWN IN 1921

Name	Rust class	Yield classes in grams													Total	Mean	Diff. P. E.
		0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75			
Victory-White Russian	Re	7	4	8	8	8	6	6	1	4	1	..	..	..	..	53	2.04±0.11	.....
Victory-White Russian	Su	3	9	4	6	6	2	1	..	..	1	..	..	..	..	32	1.56±0.12	3.0
Minota-White Russian	Re	12	13	6	11	4	8	7	6	1	3	..	1	..	..	72	1.94±0.11	.....
Minota-White Russian	Su	5	3	5	5	..	..	1	1	..	..	..	..	..	..	20	1.28±0.14	3.7

Results in the side-panicled forms (Table XV) were similar to those obtained in the open-panicled forms. In the Victory-White Russian and Minota-White Russian crosses the differences between mean yields of resistant and susceptible plants are respectively 3.0 and 3.7 times the probable errors. In the first cross the difference is approximately 24 per cent of the average yield of the resistant plants and in the second cross the difference is approximately 34 per cent of the average yield of the resistant plants. In both crosses the rust resistant plants gave the greater average yields.

TABLE XVI

AVERAGE YIELDS OF THE F_2 GENERATION OF CERTAIN OAT CROSSES GROWN IN 1921

Name	Panicle type	Rust class	No. of plants	Average yield	Diff P. E.
Victory-White Russian	open	Re	325	2.17±0.05	
Victory-White Russian	side	Re	53	2.04±0.11	1.1
Victory-White Russian	open	Su	102	1.36±0.06	1.5
Victory-White Russian	side	Su	32	1.56±0.12	
Minota-White Russian	open	Re	504	1.94±0.04	
Minota-White Russian	side	Re	72	1.94±0.11	
Minota-White Russian	open	Su	143	1.71±0.07	
Minota-White Russian	side	Su	20	1.28±0.14	2.7

From the data presented in Tables XIV and XV a comparison may be made of the average yields of F_2 plants with the same parentage and of the same rust reaction but different with respect to panicle type. To facilitate such a comparison Table XVI has been prepared. Among the resistant F_2 plants of the Victory-White Russian cross the open-panicled forms yielded on the average 0.13 grams more than the side-panicled forms. This difference is only 1.1 times the probable error. Among the susceptible F_2 plants of the same cross the average yield of the side-panicled forms was 0.20 grams more than of the open-panicled forms, a difference 1.5 times its probable error and therefore not significant. The average yields of the open- and side-panicled F_2 resistant plants of the Minota-White Russian cross were the same. Among the susceptible individuals of the same cross, 20 side-panicled forms gave an average yield of 1.28±0.14 grams, while 143 open-panicled forms gave an average yield of 1.71±0.07. The difference is about 25 per cent of the mean yield of the open-panicled plants and is 2.7 times the probable error. The odds are about 14 to 1 against the chance of such a difference being due solely to random sampling. However, the number of plants in the side-susceptible group is too small to constitute a very desirable random sample. Considering all the differences between groups of like rust reaction but unlike panicle type, no consistent correlation between panicle type and yield was found.

The F_3 families homozygous for resistance to rust but segregating for panicle type are shown in Table XVII. By using only the segregating families, each plot is represented by the two classes of plants, i. e., open resistant and side resistant. This tends to minimize the possible effect of soil heterogeneity on the relative difference between the two classes. The data from which Table XVII was prepared may be found in the appendix (Tables XXXI, XXXII, XXXIIII, and XXXIV). The mean yield of the open-panicled forms did not differ significantly from the mean yield of the side-panicled forms in the Minota-White Russian cross. However, the Victory-White Russian cross showed a difference 5.1 times the probable error between the average yields of the two panicle types. This difference is about 22 per cent of the mean yield of the open-panicled plants, the higher yielding class, and can scarcely be attributed to chance.

The frequency distributions of the individual plant yields of F_3 families homozygous for both rust resistance and panicle type are shown in Table XVIII. The difference between the mean yield of open- and side-panicled forms is significant in both crosses. In one case the difference is 7.7 and in the other 5.5 times the respective probable errors. The mean yield of the side-panicled forms of the Minota-White Russian cross is about 73 per cent of the mean yield of the open-panicled forms. In the Victory-White Russian cross the mean yield of the side-panicled forms is about 78 per cent of what it is in the open-panicled forms.

AVERAGE YIELDS OF PARENTS

The number of plants harvested, their bulk yields, and the average yields per plant per plot are given in Tables XXXV and XXXVI, of the appendix. In Table XIX the frequency distributions of the average yield per plant per plot and the probable error of the average yield of a single plot of the Minota and Victory parents are shown. In the last column of the table the average number of plants per plot is given. Both the frequency distributions and the probable errors of the average plant yield of a single plot show that the soil in that part of the nursery used to grow the Minota parent and the Minota-White Russian F_3 families was more heterogenous than the part used to grow the Victory parent and the Victory-White Russian F_3 families. The mean yield of Victory was about 65 per cent of the mean yield of Minota. Owing to the fact that Minota matures somewhat earlier than Victory it is likely that stem rust reduced the yield of the latter more than of the former. The difference in yield between the parents may of course also be partly due to a difference in the productivity of the soil in the two parts of the nursery.

TABLE XVII

Frequency Distributions of Yield of Individual Plants in Relation to Panicle Type in F_4 Families Segregating for Panicle Type but Resistant to Rust

Name	Culture No.	Panicle type	Yield classes in grams												Total	Mean	Diff/ P. E.
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25			
Segregating for panicle type																		
Minota x White Russian	4-4, etc.	open	13	27	49	49	35	24	21	7	4	2	2	2	..	235	1.95±0.05	.....
Minota x White Russian		side	7	16	20	11	17	17	8	3	0	1	1			96	1.84±0.07	1.2
Victory x White Russian and reciprocal	3-1, etc. and 2-2, etc.	open	11	32	35	44	29	25	21	13	9	4	0	1	..	221	2.06±0.05	.....
		side	7	15	12	9	9	7	5	0	0	1	..	..	..	65	1.60±0.08	5.1

TABLE XVIII

Frequency Distributions of Yield of Individual Plants in Relation to Panicle Type in F_5 Families Homozygous for Both Resistance and Panicle Type

Name	Culture No.	Panicle type	Yield classes in grams												Total	Mean	Diff/ P. E.
			0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25			
Homozygous for panicle type																		
Minota x White Russian	1-1, etc.	open	22	33	47	48	40	24	21	11	9	6	1	1	1	267	2.02±0.05	.....
Minota x White Russian		side	28	34	31	37	16	10	7	6	1	1				174	1.48±0.05	7.7
Victory x White Russian and reciprocal	3-1, etc., and 2-2, etc.	open	11	10	21	23	30	21	18	9	7	9	4	3	2	168	2.49±0.07	.....
		side	2	16	19	17	13	6	8	8	2				..	91	1.94±0.07	5.5

TABLE XIX

FREQUENCY DISTRIBUTIONS OF AVERAGE YIELD PER PLANT PER PLOT OF THE MINOTA AND VICTORY PARENTS GROWN WITH THE F_3 FAMILIES IN 1921

Name	Average yield classes in grams							Total No. of plots	Mean	P. E. of Av. plant yield of a single plot	Av. No. of plants per plot
	0.625	0.875	1.125	1.375	1.625	1.875	2.125				
										grams	
Minota	0	1	3	4	6	4	3	21	1.59±0.05	0.235	38.2
Victory	1	9	8	2	1	0	0	21	1.04±0.03	0.151	33.9

Among the F_2 generations the White Russian parent appeared in five systematically distributed plots. (Appendix Tables XXXV and XXXVI). The average yields per plant per plot were 1.86, 1.98, 2.25, 2.37, and 1.98 grams, respectively, with a mean yield of 2.09 grams. This mean yield is higher than the mean yields of the two open-panicled parents.

AVERAGE YIELDS IN MINOTA-WHITE RUSSIAN AND VICTORY-WHITE RUSSIAN F_3 FAMILIES

Before yields of the F_3 families, which were harvested by the individual plant method, could be compared with yields of the F_3 families harvested in bulk, it was necessary to make a correction. Yields of a few individual plants from each F_3 family harvested by the individual plant method were determined in two ways. First the yield of each plant was determined and then the seed from these plants was bulked and the weight of this bulk seed ascertained. This procedure was followed for each of the homozygous resistant F_3 families of which individual plant yields were determined. The data and the correction factor for each cross are shown in Table XX. The corrected total and average yields are indicated in Tables XXXV and XXXVI of the appendix. The apparent difference in yields by the two methods is owing to the fact that the smaller quantities of seed obtained from single plants were on the average underweighed by the balance used.

TABLE XX

DATA FROM WHICH CORRECTION FACTORS WERE COMPUTED

Name	Culture number	Number of plants	Yield in grams		Correction factor
			Sum of individual plant yields	Bulk yield	
Minota x White Russian	4-4, etc.	266	246.8	260.8	1.056
Victory x White Russian and reciprocal	3-1, etc. and 2-2, etc.	171	185.6	201.1	1.084

In Tables XXI and XXII are shown the frequency distributions for average yield per plant per plot of all the F_3 families in the Minota-White Russian and Victory-White Russian crosses, respectively. The frequency distributions are grouped according to the breeding nature of the F_3 families as are indicated in the three columns at the left in each table. The braces include the plant classes found in each plot. For example, the first four frequency distributions of each table are made up of plots segregating for both panicle type and rust reaction; hence with few exceptions there are open-panicled resistant and susceptible plants and side-panicled resistant and susceptible plants in each plot shown here. The mean yield of each category of plants and differences in terms of the probable errors between mean yields are shown at the right of each table. The average number of plants per plot and the probable error of the average plant yield of a single plot are recorded in the last two columns of the tables.

It will be observed, as shown in the tables, that certain frequency distributions have been combined and the mean yields and probable errors computed from these combined distributions. Such a procedure in the open-panicled susceptible, and side-panicled resistant, groups necessitated combining distributions representing considerable differences in the average number of plants per plot. However, in view of the general similarity between the two distributions combined in each case, and the magnitude of the probable error of the yield of a single plot based on an average of approximately seven plants, this method was used altho not wholly justified from a mathematical standpoint. As is expected, the magnitude of the probable error of the average plant yield of a single plot is generally less where a relatively large number of plants make up the average yield than where but a few plants make up the average yield. Nevertheless the probable errors of yields of single plots indicate that an average yield based on seven plants is almost as trustworthy as an average yield based on twenty plants.

The last four frequency distributions of each of the tables are made up from the F_3 families homozygous for both panicle type and rust reaction. The probable errors of the means in these cases are calculated from a probable error of a single determination of somewhat greater magnitude than was actually found in any frequency distribution comprising average yields based on twenty or more plants. This arbitrary method rather than a method suggested by Student (1908) was used owing to the differences in the number of F_3 families making up the various frequency distributions.

Considering first the Minota-White Russian cross (Table XXI), it is obvious that there are greater and more significant differences

between the mean yields of plants with like panicle type but unlike rust reaction than there are between the mean yields of plants with unlike panicle type but like rust reaction. In the former the differences between mean yields are 4.8, 0.5, 6.1, 5.2, 3.3, and 1.1 times their respective probable errors; whereas in the latter the differences in mean yields are 0.1, 3.9, 0.4, 0.6, 2.9, and 0.4 times their respective probable errors. In all cases the average yield of the resistant plants was greater than the average yield of the susceptible plants of the same panicle type altho in two instances the differences are not significant. Among the average yields of plants with like rust reaction but unlike panicle type there were two cases where open-panicled resistant plants gave significantly greater yields than side-panicled resistant plants. On the average, reaction to stem rust had more influence on yield than panicle type. The average yield per plot of the open panicled susceptible plants is about 76 per cent of that in the open-panicled resistant plants, whereas among the side-panicled forms the average yield per plot of the susceptible plants is about 86 per cent of that in the resistant plants.

In the Victory-White Russian cross (Table XXII) the data show that susceptibility to rust reduced the yield even more than in the Minota-White Russian cross. On the other hand no highly significant difference was found between mean yields of plants with like rust reaction but unlike panicle type. The differences between mean yields based on rust reaction are 7.0, 5.5, 7.8, 4.4, 8.4, and 4.0 times the respective probable errors and the differences between mean yields based on panicle type are 0.1, 1.0, 0.9, 1.4, 0.4, and 2.3 times the respective probable errors. In the former case the differences are all significant and in the latter case none is significant with one possible exception. The average yield per plot of the open-panicled susceptible plants is approximately 63 per cent of that in the open-panicled resistant plants and among the side-panicled forms the average yield per plot of the susceptible plants is about 70 per cent of that in the resistant plants. On the average the F_3 families of the Victory-White Russian cross were later in maturing than those of the Minota-White Russian cross. This fact undoubtedly accounts at least in part for the apparently greater effect of rust in reducing yield in the Victory-White Russian F_3 families.

TABLE XXI

FREQUENCY DISTRIBUTIONS OF AVERAGE YIELD PER PLANT PER PLOT OF THE MINOTA-WHITE RUSSIAN F_3 FAMILIES (CULTURES 4-4, ETC.) GROWN IN 1921

F_3 families	Panicle type	Rust class	Average yield classes in grams											Total number of plots	Mean	Rust class Diff./P. E.	Panicle type Diff./P. E.	Av. No. of plants per plot	P. E. of Av. plant yield of a single plot
			0.375	0.625	0.875	1.125	1.375	1.625	1.875	2.125	2.375	2.625	2.875	3.125					grams
Segregating for both panicle type and rust reaction	open	Re	..	..	..	..	2	3	5	6	3	4	..	..	23	2.06±0.05	.....	.....	22.4	0.255
	open	Su	..	1	1	2	3	4	7	4	..	1	..	..	23	1.68±0.06	4.8	0.1	7.0	0.302
	side	Re	..	..	1	..	7	5	4	4	..	1	1	..	23	1.75±0.06	.....	3.9	7.2	0.298
	side	Su	1	..	2	2	5	2	4	2	3	1	1	..	23	1.69±0.09	0.5	.....	2.7	0.408
Homozygous open, segregating for rust	open	Re	..	..	1	1	1	1	3	2	1	..	..	..	10	*a*	.....	.....	27.9	.....
	open	Su	..	2	1	1	3	3	..	..	..	..	..	..	10	*b*	.....	.....	9.3	.....
Homozygous side, segregating for rust	side	Re	..	..	1	..	2	1	1	2	1	1	..	..	9	*c*	.....	.....	26.7	.....
	side	Su	..	..	1	1	4	2	..	..	1	..	..	..	9	*d*	.....	.....	9.1	.....
Homozygous resistant, segregating for panicles	open	Re					.	3	4	1	1	1	..	1	11	1.90±0.07*a*	.....	.....	24.0	0.324
	side	Re	..	..	.	..	2	4	2	1	.	1	.	1	11	1.86±0.08*c*	.....	0.4	9.6	0.352
Homozygous susceptible, segregating for panicles	open	Su	.	.	.	1	7	3	1	..			..	..	12	1.35±0.05*b*	6.1	0.6	28.7	0.209
	side	Su	..	.	2	3	2	5	..	..	..	..	..	..	12	1.39±0.05*d*	5.2	. .	8.6	0.230
Open resistant	..	..	.	.	..	..	.	1	5	2	.	1	1	..	10	2.08±0.11*	..	..	30.4	..
Open susceptible	..	..	..	..	..	..	1	2	1	..	..	..	..	..	4	1.38±0.18*	3.3	.	38.8	.....
Side resistant	..	..	..	..	..	1	1	2	1	..	..	..	..	..	5	1.53±0.16*	.....	2.9	34.8	.....
Side susceptible	..	..	..	..	1	1	2	1	.	..	.	..	..	..	5	1.28±0.16*	1.1	0.4	39.4	.....

a, *b*, *c*, *d*. Frequency distributions marked with the same letter were combined before calculating the constants.

* Probable error calculated on the basis of 0.350 as the probable error of a single determination.

TABLE XXII

FREQUENCY DISTRIBUTIONS OF AVERAGE YIELD PER PLANT PER PLOT OF THE VICTORY-WHITE RUSSIAN F_2 FAMILIES (CULTURES 3-1, ETC. AND 2-2, ETC.), GROWN IN 1921

F_2 families	Panicle type	Rust class	Average yield classes in grams: 0.375	0.625	0.875	1.125	1.375	1.625	1.875	2.125	2.375	2.625	2.875	3.125	3.375	3.625	3.875	Total number of plots	Mean	Rust class Diff./P. E.	Panicle type Diff./P. E.	Av. No. of plants per plot	P. E. of Av. plant yield of a single plot
																							grams
Segregating for both panicle type and rust reaction	open	Re			1	1	3	3	7	6	8	3	2	1	..	..	..	35	2.08±0.06	.....	.....	19.5	0.337
	open	Su	1	3	1	9	6	8	2	2	2	..	..	..	1	..	..	35	1.45±0.07	7.0	0.1	7.2	0.372
	side	Re		..	1	7	8	5	2	4	3	3	2	..	..	..	..	35	1.99±0.07	.....	1.0	4.8	0.383
	side	Su		5	5	6	1	5	3	5	2	1	..	..	..	..	..	33	1.44±0.07	5.5	.....	3.2	0.403
Homozygous open, segregating for rust	open	Re			..	..	1	2	3	1	3	..	..	..	..	..	..	10	*a*	.....	.....	23.2	.....
	open	Su	1	..	4	2	1	1	..	..	..	1	..	..	..	..	..	10	*b*	.....	.....	9.5	.....
Homozygous side, segregating for rust	side	Re	..	.			.	2	..	2	1	1	..	..	..	..	..	6	*c*	.....	.....	26.0	.....
	side	Su		.	2	2	..	1	1	..	..	..	..	..	..	..	..	6	*d*	.....	.....	7.7	.....
Homozygous resistant, segregating for panicles	open	Re		.	.	.	1	3	1	1	2	1	1	1	..	..	..	11	2.05±0.07*a*	.....	.....	22.3	0.317
	side	Re		.	.	1	4	..	1	2	2	..	..	1	..	..	..	11	1.95±0.09*c*	.....	0.9	6.5	0.355
Homozygous susceptible, segregating for panicles	open	Su		..	1	5	1	4	1	..	..	..	..	..	..	..	..	12	1.27±0.07*b*	7.8	1.4	22.2	0.308
	side	Su	.	1	2	1	2	2	..	4	..	..	..	..	..	..	..	12	1.42±0.08*d*	4.4	.....	7.7	0.334
Open resistant	.	.						1	1	..	..	1	1	1	..	..	1	6	2.67±0.14*	.....	.....	28.0	.....
Open susceptible			2	1	2	1	1	1	..	..	..	..	..	..	..	..	..	8	1.16±0.12*	8.4	0.4	34.4	.....
Side resistant	..	.	.	.	.	.	.	1	1	.	.	.	1	..	.	.	..	3	2.13±0.20*	...	2.3	30.3	.
Side susceptible	.	.	.	1	3	4	..	..	..	..	..	..	..	..	..	..	..	8	1.22±0.12*	4.0	.....	37.0	.....

a, *b*, *c*, *d*, Frequency distributions marked with the same letter were combined before calculating the constants.

* Probable error calculated on the basis of 0.350 as the probable error of a single determination.

DISCUSSION

The difference in the parasitic reaction of the pure line hosts, Victory, Minota, and White Russian oats to the fungus stem rust is because of physiological rather than morphological characters. The parasite gains admittance to all three oat varieties but does not develop equally well in all. A heavily infected White Russian plant manifests many small uredinia, whereas a Victory or Minota plant, under the same condition, manifests many large uredinia; in some cases considerable areas of the surface of the oat stem, particularly near the nodes, become entirely covered with rust spores. Resistance to rust is relative, not absolute.

The difference in host reaction to rust is a character definitely inherited. If Victory or Minota is crossed with White Russian, the F_2 generation consists of two kinds of plants, namely, resistant and susceptible. The reaction to rust of approximately three fourths of the F_2 plants is like that of the resistant parent and of one fourth like that of the susceptible parent. The F_2 plants produce three kinds of F_3 families. Seed from susceptible F_2 individuals gives rise to susceptible progeny, whereas seed from approximately one third of the resistant F_2 individuals produces resistant progeny, and seed from the other two thirds produces progeny which again show segregation in the ratio of three resistant to one susceptible plant. The difference in rust reaction between the parents is apparently due to a single factor difference.

Some evidence is also shown for assuming that a single main factor difference between the parents is operating in the inheritance of panicle type. The resistant parent is side-panicled and the susceptible parents are open-panicled forms. The segregation of the F_2 generation and the frequency with which side-panicled susceptible, and open-panicled resistant F_3 families are obtained indicate that rust reaction and panicle type are not closely linked in inheritance.

Yield of seed in oats is materially decreased by the action of stem rust. The two important characteristics of host plants which largely determine the extent of the decrease in yield are length of time required to mature and reaction to the parasitic fungus. Other things being equal, an early maturing variety of oats has a better chance to escape injurious rust infection than a later maturing variety. In the present investigation the extent of the decrease in yield of seed caused primarily by stem rust was measured. In nearly all cases the mean yield of resistant plants was significantly greater than the mean yield of similar plants but susceptible to rust. The genotypes of the plants compared differed of course in other respects than rust reaction, but the number

of plants on which yield determinations were made is sufficiently great to place considerable confidence in the results. It is of interest to note that the average reduction of yield because of rust is greater in the Victory-White Russian progeny than it is in the Minota-White Russian progeny. The former averaged somewhat later in maturing than the latter.

SUMMARY

1. Two open-panicled pure lines of oats, Minota and Victory, which are susceptible to stem rust, were crossed with a side-panicled pure line of White Russian oats which is relatively resistant to stem rust. The inheritance of host reaction to rust, panicle type, and pollen abortion were studied in the F_1, F_2, and F_3 generations. A study was also made of the correlation between rust reaction and yield and between panicle type and yield during one of the three years the investigation was in progress.

2. The relative length and breadth of the stomata through the guard cells on the under surface of the leaves of nearly matured plants of the Victory and White Russian oat strains used in this investigation indicate that the rust resistance of White Russian is not owing to relative size of stomata. This conclusion was corroborated by the relative width of the stomatal openings when at a maximum in the seedlings of the same varieties.

3. Rust resistance is inherited as a dominant character depending on a single factor difference for its expression. In both crosses, Minota-White Russian and Victory-White Russian, 3044 F_2 plants and 377 F_3 families were examined for their reaction to rust. In all, the F_2 generations consisted of 2340 resistant and 704 susceptible plants. Of the F_3 families, 106 bred true for resistant, 175 segregated in the ratio of three resistant to one susceptible plant, and 96 bred true for susceptibility. The segregating F_3 families produced 5964 resistant and 1970 susceptible plants.

4. In the above crosses panicle type is dependent on a single main factor for its expression. The F_1 plants were open-panicled but not to the same degree as the open-panicled parents. In all the F_3 families of both crosses there were 98 homozygous open, 213 showing segregation, and 66 homozygous side.

5. Evidence is presented which indicates that panicle type and rust reaction are nearly, if not completely, independent in their inheritance.

6. The Victory parent produced on the average 12.4 per cent aborted pollen. Minota and White Russian produced on the average 1.0 and 0.9 per cent aborted pollen, respectively. In the Victory-White

Russian cross of 250 F_2 plants, 7 produced percentages of aborted pollen within the range exhibited by the Victory parent.

7. In 1921 the F_2 and F_3 generations were analyzed to determine the potency of rust in reducing yield of seed. In the F_2 generations the approximate average reduction of yield because of rust in the Minota-White Russian cross was 12 per cent among the open-panicled forms and 34 per cent among the side-panicled forms; and in the Victory-White Russian cross 37 per cent among the open panicled plants and 24 per cent among the side-panicled plants; in the F_3 generations the average percentage reductions of yield were 24, 14, and 37, 30 in the two crosses, respectively.

8. The correlation between panicle type and yield was not consistent. However, in every instance where a significant difference was found, the open-panicled forms gave the greater average yields. The approximate percentage differences between average yields of all the plants of the same parentage and rust reaction but different panicle type are given below. Percentages are based on the average yield of the open-panicled type in each case. Considering first the plants harvested individually, the resistant open-panicled plants of the Victory-White Russian cross yielded 16 per cent more than the resistant side-panicled plants. Among the susceptible plants of the same cross, the side-panicled type yielded 15 per cent more than the open-panicled type. In the Minota-White Russian cross the average yield of the open-panicled resistant forms exceeded that of the side-panicled resistant forms by 14 per cent, whereas among the susceptible plants, forms with open panicles yielded on the average 25 per cent more than forms with side panicles. Considering the bulk yields, differences also appear. Of the two panicle types in the Minota-White Russian cross, the open-panicled type gave the greater average yield (12 per cent) among the resistant plants and the side-panicled type gave slightly the greater average yield (about 1 per cent) among the susceptible plants. In the Victory-White Russian cross, the open-panicled resistant plants yielded 7 per cent more and the side-panicled susceptible plants 4 per cent more than the plants of the same rust reaction but of different panicle type.

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APPENDIX

TABLE XXIII

WHITE RUSSIAN x VICTORY F_3 PROGENIES, GROWN IN 1920, SHOWING RUST REACTION AND PANICLE TYPE

Culture number	No. of plants*		Panicle type†		
	Re	Su	O	H	S
2-13- 1	35	17			x
2-13- 2	62	16			x
2-13- 3	.....	21		x	
2-13- 4	.....	21		x	
2-13- 5	.....	21		x	
2-13- 6	77	.....		x	
2-13- 7	68	17	x		
2-13- 8	73	.....		x	
2-13- 9	.....	20		x	
2-13-10	55	31		x	
2-13-11	22	.....		x	
2-13-12	19	.....			x
2-13-13	59	22		x	
2-13-14	58	.....		x	
2-13-15	65	18		x	
2-13-16	52	19			x
2-13-17	78	.....		x	
2-13-18	79	.....		x	
2-13-19	.....	19	x		
2-13-20	.....	41			x
2-13-21	72	.....		x	
2-13-22	15	6			x
2-13-23	83	.....		x	
2-13-24	64	.....		x	
2-13-25	44	.....		x	
2-13-26	13	.....			x
2-13-27	.....	19	x		
2-13-28	13	5		x	
2-13-30	12	.....		x	
2-13-31	15	.....			x
2-13-32	35	12	x		
2-13-33	.....	20	x		
2-13-34	.....	13	x		
2-13-35	13	.....	x		
2-13-36	11	3		x	
2-13-37	24	9	x		
2-13-38	27	.....		x	
2-13-39	16	.....			x
2-13-40	17	.....		x	
2-13-41	6	2	x		

*Re = resistant; Su = susceptible. †O = open; H = segregating; S = side.

TABLE XXIV

WHITE RUSSIAN x VICTORY F_3 PROGENIES, GROWN IN 1921, SHOWING RUST REACTION AND PANICLE TYPE

Culture number	No. of plants*		Panicle type†			Culture number	No. of plants*		Panicle type†		
	Re	Su	O	H	S		Re	Su	O	H	S
2-2- 1	11	22		x		2-2-26	21	10	x		
2-2- 2	27	5		x		2-2-27	.....	32		x	
2-2- 3	30	9		x		2-2-28	30	6			x
2-2- 4	32	.....	x			2-2-29	.....	41			x
2-2- 5	31	10		x		2-2-30	.....	36			x
2-2- 6	27	10	x			2-2-31	22	15		x	
2-2- 7	27	.....		x		2-2-32	29	.....		x	
2-2- 8	34	.....		x		2-2-33	.....	33	x		
2-2- 9	25	10	x			2-2-34	29	.....			x
2-2-10	.....	24			x	2-2-35	30	.....	x		
2-2-11	33	7		x		2-2-36	26	9		x	
2-2-12	.....	34		x		2-2-37	18	.....	x		
2-2-13	26	.....			x	2-2-38	29	8		x	
2-2-14	5	26		x		2-2-39	24	9		x	
2-2-15	24	7			x	2-2-40	27	.....		x	
2-2-16	.....	24		x		2-2-41	23	7		x	
2-2-17	.....	36			x	2-2-42	13	26		x	
2-2-18	.....	41			x	2-2-43	.....	11		x	
2-2-19	24	13		x		2-2-44	17	11		x	
2-2-20	23	9			x	2-2-45	20	7	x		
2-2-21	27	11		x		2-2-46	29	6		x	
2-2-22	28	11		x		2-2-47	25	6		x	
2-2-23	31	8		x		2-2-48	17	7			x
2-2-24	23	6	x			2-2-49	26	10		x	
2-2-25	25	.....		x		2-2-50	.....	39			x

*Re = resistant; Su = susceptible. †O = open; H = segregating; S = style.

TABLE XXV

WHITE RUSSIAN x VICTORY F_3 PROGENIES, GROWN IN 1921, SHOWING RUST REACTION AND PANICLE TYPE

Culture number	No. of plants*		Panicle type†			Culture number	No. of plants*		Panicle type†		
	Re	Su	O	H	S		Re	Su	O	H	S
3-1- 1	29	.....	x			3-1-26	.....	36	x		
3-1- 2	.....	39	x			3-1-27	21	7		x	
3-1- 3	11	13		x		3-1-28	19	14		x	
3-1- 4	36	.....			x	3-1-29	.....	31		x	
3-1- 5	23	6			x	3-1-30	27	7			x
3-1- 6	.....	33		x		3-1-31	26	9		x	
3-1- 7	.....	20	x			3-1-32	.....	41	x		
3-1- 8	25	7	x			3-1-33	15	17	x		
3-1- 9	.....	42			x	3-1-34	.....	38		x	
3-1-10	31	.....		x		3-1-35	.....	36	x		
3-1-11	28	8		x		3-1-36	.....	34	x		
3-1-12	.....	35		x		3-1-37	31	7	x		
3-1-13	28	12		x		3-1-38	34	6		x	
3-1-14	29	8		x		3-1-39	.....	34		x	
3-1-15	30	.....		x		3-1-40	24	11		x	
3-1-16	.....	37			x	3-1-41	25	7		x	
3-1-17	27	.....		x		3-1-42	30	.....		x	
3-1-18	21	6		x		3-1-43	27	8		x	
3-1-19	27	.....		x		3-1-44	30	6		x	
3-1-20	.....	31		x		3-1-45	29	.....		x	
3-1-21	26	6	x			3-1-46	31	.....	x		
3-1-22	33	7		x		3-1-47	29	11			x
3-1-23	19	15	x			3-1-48	16	5		x	
3-1-24	.....	36	x			3-1-49	29	.....	x		
3-1-25	.....	23		x		3-1-50	.....	32		x	

*Re = resistant; Su = susceptible. †O = open; H = segregating; S = side.

TABLE XXVI

MINOTA x WHITE RUSSIAN F_3 PROGENIES, GROWN IN 1920, SHOWING RUST REACTION AND PANICLE TYPE

Culture number	No. of plants*		Panicle type†			Culture number	No. of plants*		Panicle type†		
	Re	Su	O	H	S		Re	Su	O	H	S
4-7- 1	73	.....		x		4-7-23	18	.....		x	
4-7- 2	.....	21			x	4-7-24	31	8			x
4-7- 3	68	.....	x			4-7-25	40	17		x	
4-7- 4	32	6			x	4-7-26	70	.....	x		
4-7- 5	73	14			x	4-7-27	.....	16		x	
4-7- 6	82	.....		x		4-7-28	76	.....		x	
4-7- 7	66	19		x		4-7-29	72	.....	x		
4-7- 8	64	13		x		4-7-30	33	12		x	
4-7- 9	.....	45		x		4-7-31	66	14	x		
4-7-11	82	.....	x			4-7-32	.....	25		x	
4-7-12	19	.....		x		4-7-33	66	13		x	
4-7-13	.....	35		x		4-7-34	52	12		x	
4-7-14	79	.....		x		4-7-35	88	.....		x	
4-7-15	29	6	x			4-7-36	.....	15			x
4-7-16	67	13		x		4-7-37	68	.....		x	
4-7-17	.....	21	x			4-7-38	.....	76		x	
4-7-18	76	.....		x		4-7-39	.....	73	x		
4-7-19	73	14		x		4-7-40	16	3		x	
4-7-20	56	23		x		4-7-41	64	20		x	
4-7-21	64	.....	x			4-7-42	60	7		x	
4-7-22	59	21	x			4-7-43	6	2			x
						4-7-44	72	.....		x	
						4-7-45	.....	21		x	

*Re = resistant; Su = susceptible. †O = open; H = segregating; S = side.

TABLE XXVII

MINOTA xWHITE RUSSIAN F_3 PROGENIES, GROWN IN 1920, SHOWING RUST REACTION AND PANICLE TYPE

Culture number	No. of plants*		Panicle type†			Culture number	No. of plant*		Panicle type†		
	Re	Su	O	H	S		Re	Su	O	H	S
4-8- 1	.....	19		x		4-8-26	54	24	x		
4-8- 2	.....	19		x		4-8-27	69	.....		x	
4-8- 3	.....	20		x		4-8-28	.....	19		x	
4-8- 4	64	21		x		4-8-29	76	.....		x	
4-8- 5	55	20		x		4-8-30	64	23		x	
4-8- 6	.....	18			x	4-8-31	68	16		x	
4-8- 7	74	.....		x		4-8-32	60	21		x	
4-8- 8	58	17		x		4-8-33	82	.....			x
4-8- 9	4	8	x			4-8-34	55	21	x		
4-8-10	33	.....	x			4-8-35	54	21	x		
4-8-11	23	.....		x		4-8-36	.....	21	x		
4-8-12	.....	21	x			4-8-37	59	.....			x
4-8-13	55	14		x		4-8-38	66	18		x	
4-8-14	81	.....	x			4-8-39	43	12	x		
4-8-15	16	5	x			4-8-40	80	.....		x	
4-8-16	.....	19	x			3-8-41	71	.....		x	
4-8-17	.....	38			x	4-8-42	.....	19	x		
4-8-18	76	.....	x			4-8-43	70	.....		x	
4-8-19	19	.....			x	4-8-44	51	25		x	
4-8-20	57	26	x			4-8-45	90	.....		x	
4-8-21	.....	16			x	4-8-46	.....	22		x	
4-8-22	67	18		x		4-8-47	68	17		x	
4-8-23	.....	19		x		4-8-48	67	24		x	
4-8-24	.....	22	x			4-8-49	75	.....		x	
4-8-25	.....	18	x			4-8-50	.....	19	x		

*Re = resistant; Su = susceptible. †O = open; H = segregating; S = side.

TABLE XXVIII

MINOTA x WHITE RUSSIAN F_3 PROGENIES, GROWN IN 1920, SHOWING RUST REACTION AND PANICLE TYPE

Culture number	No. of plants*		Panicle type†			Culture number	No. of plants*		Panicle type†		
	Re	Su	O	H	S		Re	Su	O	H	S
4-9- 1	.....	18		x		4-9-25	19	.....			x
4-9- 2	15	6			x	4-9-26	.....	18	x		
4-9- 3	.....	22		x		4-9-27	28	6	x		
4-9- 4	70	16		x		4-9-28	26	8		x	
4-9- 5	14	5			x	4-9-29	10	.....	x		
4-9- 6	18	.....			x	4-9-31	43	29		x	
4-9- 7	76	33		x		4-9-32	42	.....		x	
4-9- 8	.....	21		x		4-9-33	84	.....		x	
4-9- 9	57	25	x			4-9-34	55	24	x		
4-9-10	39	10		x		4-9-35	64	15		x	
4-9-11	36	.....		x		4-9-36	45	10		x	
4-9-12	.....	20		x		4-9-38	64	17		x	
4-9-13	12	5			x	4-9-39	63	.....		x	
4-9-14	40	6		x		4-9-40	10	3			x
4-9-16	.....	19		x		4-9-41	53	16	x		
4-9-18	13	4		x		4-9-42	9	1	x		
4-9-19	65	.....		x		4-9-43	20	.....	x		
4-9-20	.....	16		x		4-9-44	.....	17		x	
4-9-21	80	.....	x			4-9-45	51	11	x		
4-9-22	82	.....	x			4-9-46	7	3		x	
4-9-23	17	3		x		4-9-47	15	3			x
4-9-24	28	.....	x								

*Re = resistant; Su = susceptible. †O = open; H = segregating; S = side.

TABLE XXIX

MINOTA x WHITE RUSSIAN F_2 PROGENIES GROWN IN 1921, SHOWING RUST REACTION AND PANICLE TYPE

Culture number	No. of plants*		Panicle type†			Culture number	No. of plants*		Panicle type†		
	Re	Su	O	H	S		Re	Su	O	H	S
4-4- 1	28	.....		x		4-4-40	28	.....	x		
4-4- 2	32	3		x		4-4-41	37	6		x	
4-4- 3	30	4		x		4-4-42	28	.....		x	
4-4- 4	36	.....	x			4-4-43	.....	30	x		
4-4- 5	28	6		x		4-4-44	31	6		x	
4-4- 6	38	.....			x	4-4-45	.....	37	x		
4-4- 7	25	10		x		4-4-46	31	4	x		
4-4- 8	35	5	x			4-4-47	.....	37		x	
4-4- 9	29	8	x			4-4-48	27	7		x	
4-4-10	28	11		x		4-4-49	.....	43		x	
4-4-11	23	15	x			4-4-50	25	.....	x		
4-4-12	37	.....		x		4-4-51	28	9	x		x
4-4-13	24	12		x		4-4-52	25	12			
4-4-14	24	13		x		4-4-53	29	7	x		
4-4-15	33	12		x		4-4-54	26	15	x		
4-4-16	20	12	x			4-4-55	.....	41			x
4-4-17	32	.....			x	4-4-56	.....	38		x	
4-4-18	19	.....	x			4-4-57	28	16		x	
4-4-19	.....	37		x		4-4-58	21	8			
4-4-20	30	.....	x			4-4-59	33	8	x		x
4-4-21	.....	37		x		4-4-60	.....	42			x
4-4-22	26	10		x		4-4-61	.....	34		x	
4-4-23	30	.....			x	4-4-62	27	.....		x	
4-4-24	27	6			x	4-4-63	.....	34		x	
4-4-25	30	6		x		4-4-64	25	7		x	
4-4-26	29	4			x	4-4-65	31	11			x
4-4-27	.....	40	x			4-4-66	.....	40			x
4-4-28	29	.....		x		4-4-67	39	.....		x	
4-4-29	31	12		x		4-4-68	23	7		x	
4-4-3	2	1		x		4-4-69	39	.....		x	
4-4-31	.....	43		x		4-4-70	29	12		x	
4-4-32	.....	37		x		4-4-71	35	6		x	
4-4-33	.....	29		x		4-4-72	.....	35		x	
4-4-34	33	10		x		4-4-73	.....	31		x	
4-4-35	.....	38	x			4-4-74	30	8		x	
4-4-36	29	9		x		4-4-75	35	.....		x	
4-4-37	.....	35		x		4-4-76	27	13			x
4-4-38	.....	39			x	4-4-77	31	10		x	
4-4-39	37	6		x		4-4-78	35	.....	x		

*Re = resistant; Su = susceptible. †O = open; H = segregating, S = side

TABLE XXIX—*Continued*

MINOTA x WHITE RUSSIAN F_3 PROGENIES GROWN IN 1921 SHOWING RUST REACTION AND PANICLE TYPE

Culture number	No. of plants*		Panicle type†			Culture number	No. of plants *		Panicle type†		
	Re	Su	O	H	S		Re	Su	O	H	S
4-4-79	38	.....			x	4-4-90	.....	39	x		
4-4-80	29	11			x	4-4-91	23	11		x	
4-4-81	35	.....		x		4-4-92	37	.....			x
4-4-82	35	.....		x		4-4-93	.....	38	x		
4-4-83	37	.....	x			4-4-94	20	5			x
4-4-84	.....	35			x	4-4-95	39	.....		x	
4-4-85	25	10	x			4-4-96	32	9		x	
4-4-86	31	.....	x			4-4-97	34	8		x	
4-4-87	31	.....	x			4-4-98	.....	42		x	
4-4-88	35	8		x		4-4-99	32	.....	x		
4-4-89	29	10			x	4-4-100	29	8			x

*Re =resistant; Su =susceptible. †O =open; H =segregating; S =side.

TABLE XXX

SEGREGATION OF F_2 PLANTS WITH RESPECT TO RUST REACTION AND PANICLE TYPE AS REVEALED BY THEIR F_3 PROGENIES. (TABLES XXIII TO XXIX INCLUSIVE)

Name	Culture number	Year F_3 was grown	No. of F_2 plants								
			Homozygous resistant			Heterozygous resistant			Homozygous susceptible		
			Panicle type			Panicle type			Panicle type		
			Open	Segregating	Side	Open	Segregating	Side	Open	Segregating	Side
White Russian x Victory	2-13	1920	1	13	4	4	5	4	4	4	1
White Russian x Victory	2-2	1921	3	5	2	5	20	4	1	4	6
Victory x White Russian	3-1	1921	3	6	1	5	15	3	7	8	2
Minota x White Russian	4-7	1920	5	10	0	3	12	4	2	6	2
Minota x White Russian	4-8	1920	3	9	3	7	12	0	7	6	3
Minota x White Russian	4-9	1920	5	5	2	6	12	5	1	7	0
Minota x White Russian	4-4	1921	10	11	5	10	29	10	6	14	5

TABLE XXXI

FREQUENCY DISTRIBUTIONS OF INDIVIDUAL PLANT YIELD IN OPEN-PANICLED, RUST-RESISTANT F_3 PROGENY OF MINOTA x WHITE RUSSIAN CROSS

Culture number	Yield classes in grams												Total number
	0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	
4-4-1	1	7	2	6	2	1			1					20
4-4-4*	1	2	3	9	6	5	1	5	2	1	1			36
4-4-12	2	3	3	5	1	2	3	1						20
4-4-18*	2	4	2	4	4		1	1	1					19
4-4-20*	6	7	6	1	4	2	2			1	1			30
4-4-28		2	7	5	4	3								21
4-4-40*	2	4	8	5	4	2	1		2					28
4-4-42		4	6	7	2	1			1					21
4-4-50*	1	1	9	6	2	1	5							25
4-4-62	3		4	4	5	2	1	1						20
4-4-67	2	1	8	3	3	2	5	2	1	1	1			29
4-4-75		1	1	4	5	2	5	3		1	1	2		25
4-4-78*	3	2	6	5	7	6	4	1		1				35
4-4-81	1	4	8	4	4	4	3							28
4-4-82	3	3	5	6	4	1	2							24
4-4-86*	3	4	5	7	5	3	1	2				1		31
4-4-87*	1	3	3	4	3	5	3	2	3	3	1			31
4-4-95	1	2	5	5	5	6	2		1					27
4-4-99*	3	6	5	7	5		3		1		1		1	32

*Homozygous for panicle type.

TABLE XXXII

FREQUENCY DISTRIBUTIONS OF INDIVIDUAL PLANT YIELD IN SIDE-PANICLED, RUST-RESISTANT F_3 PROGENY OF MINOTA x WHITE RUSSIAN CROSS

Culture number	Yield classes in grams											Total number
	0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	
4-4-1	1	2	1	1	1	2						8
4-4-6*	7	8	6	7	5	4		1				38
4-4-12		2	6	5	2	1						16
4-4-17*	5	7	4	8	3		2	2				31
4-4-23*	2	7	7	7	2	2	3					30
4-4-28	1	3	2		2							8
4-4-42		2	2		1		2					7
4-4-62	1	1	4			1						7
4-4-67	1	2		1	2	4						10
4-4-75				1	2	2	3	1		1		10
4-4-79*	5	4	8	8	3	3	2	3	1	1		38
4-4-81	1	2	1	1	1		1					7
4-4-82	2	2	2	1	2		1	1				11
4-4-92*	9	8	9	7	3	1						37
4-4-95			2	1	4	2	1	1			1	12

*Homozygous for panicle type.

TABLE XXXIII

FREQUENCY DISTRIBUTIONS OF INDIVIDUAL PLANT YIELD IN OPEN-PANICLED, RUST-RESISTANT F_3 PROGENY OF VICTORY x WHITE RUSSIAN AND THE RECIPROCAL CROSSES

Culture number	Yield classes in grams												Total number
	0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	
3-1-1*	1		2		5	4	3	1	3	5	3	2		29
3-1-10	1	2	1	5	6	4	3	2	1					25
3-1-15	5	6	4	4		2			3					24
3-1-17	1	2	3	5	4	2	3					1		21
3-1-19		2	3	2	4	6		2						19
3-1-42	1	2	1	5	3	5	8	1	1	1				28
3-1-45		2	3	2	3	1	2	1						14
3-1-46*	2	1	5	7	6	1	3	1	1	2		1	1	31
3-1-49*			2	7	5	4	5	3	2	1				29
2-2-4*		2	6		3	9	5	3	1	1	1		1	32
2-2-7	2	5	8	4	1									20
2-2-8		3	2	3	2	2	4	7	4	2				29
2-2-25		2	5	8	2	3								20
2-2-32	1	6	5	6	4		1			1				24
2-2-35*	4	3	3	8	7	2	2							29
2-2-37*	4	4	3	1	4	1		1						18

*Homozygous for panicle type.

TABLE XXXIV

FREQUENCY DISTRIBUTIONS OF INDIVIDUAL PLANT YIELD IN SIDE-PANICLED, RUST RESISTANT F_3 PROGENY OF VICTORY x WHITE RUSSIAN AND RECIPROCAL CROSSES

Culture number	Yield classes in grams										Total number
	0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75	
3-1-4*	1	4	2	3	7	2	8	7	2		36
3-1-10		1		1	1	2	1				6
3-1-15		1	1	2	1	1					6
3-1-17		2	1	1			1			1	6
3-1-19	2	3			2	1					8
3-1-42					1		1				2
3-1-45	2	5	3	2	1	1	1				15
2-2-7	1	3	2				1				7
2-2-8			2	1	1	1					5
2-2-13*	1	6	4	8	4	2		1			26
2-2-25	2		1	1	1						5
2-2-32			2	1	1	1					5
2-2-34*		6	13	6	2	2					29

*Homozygous for panicle type.

TABLE XXXV

PLANTING PLAN AND YIELDS OBTAINED IN THAT PART OF THE NURSERY USED TO GROW THE PARENTS AND THE MINOTA-WHITE RUSSIAN F$_2$ FAMILIES IN 1921. PARENTS AND PROGENY ARRANGED IN THE ORDER IN WHICH THEY APPEARED IN THE NURSERY

Culture number or parent	Open panicles						Side panicles					
	Resistant			Susceptible			Resistant			Susceptible		
	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield
		grams	grams		grams	grams		grams	grams		grams	grams
White Russian							32	59.4	1.86			
Minota				36	61.2	1.70						
4-4-1	20	31.7†	1.59				8	13.2†	1.65			
4-4-2	Eliminated											
4-4-3	Eliminated											
4-4-4	36	94.0†	2.61									
4-4-5	Eliminated											
Minota*				32	27.9	0.87						
4-4-6							38	56.5†	1.49			
4-4-7	16	21.2	1.33	6	6.0	1.00	9	14.6	1.62	4	4.0	1.00
4-4-8	35	74.7	2.13	5	7.5	1.50						
4-4-9	29	44.4	1.53	8	5.7	0.71						
4-4-10	20	53.5	2.68	7	18.8	2.69	8	14.2	1.78	4	7.0	1.75
Minota				42	75.1	1.79						
4-4-11	23	44.7	1.94	15	24.8	1.65						
4-4-12	20	38.5†	1.93				16	26.4†	1.65			
4-4-13	15	32.0	2.13	10	20.8	2.08	9	11.7	1.30	2	3.6	1.80
4-4-14	15	25.2	1.68	9	10.6	1.18	9	12.0	1.33	4	6.1	1.53
4-4-15	26	52.5	2.02	10	17.0	1.70	7	14.6	2.09	2	2.8	1.40
Minota				43	83.7	1.95						
4-4-16	20	48.2	2.41	12	15.1	1.26						
4-4-17							31	48.8†	1.57			
4-4-18	19	35.1†	1.85									
4-4-19				30	35.8	1.19				7	7.0	1.00
4-4-20	30	49.6†	1.65									
Minota				45	77.6	1.72						
4-4-21				29	39.6	1.37				8	13.1	1.64
4-4-22	17	36.5	2.15	7	14.2	2.03	9	16.0	1.78	3	5.1	1.70
4-4-23							30	49.1†	1.64			
4-4-24	Eliminated											
4-4-25	Eliminated											
Minota*				36	36.3	1.01						
4-4-26							29	22.3	0.77	4	3.9	0.98
4-4-27				40	59.5	1.49						
4-4-28	21	38.3†	1.82				8	10.0†	1.25			
4-4-29	23	37.0	1.61	9	8.2	0.91	8	13.5	1.69	3	4.1	1.37
4-4-30	23	46.2	2.01	9	12.3	1.37	5	7.8	1.56	1	0.3	0.30

*Injured. †Corrected yield (See Table XX).

TABLE XXXV—*Continued*

PLANTING PLAN AND YIELDS OBTAINED IN THAT PART OF THE NURSERY USED TO GROW THE PARENTS AND THE MINOTA-WHITE RUSSIAN F_3 FAMILIES IN 1921. PARENTS AND PROGENY ARRANGED IN THE ORDER IN WHICH THEY APPEARED IN THE NURSERY

Culture number or parent	Open panicles						Side panicles					
	Resistant			Susceptible			Resistant			Susceptible		
	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield
		grams	grams		grams	grams		grams	grams		grams	grams
Minota				41	48.3	1.18						
4-4-31				32	47.1	1.47				11	13.9	1.26
4-4-32				27	35.8	1.33				10	13.4	1.34
4-4-33				21	35.5	1.69				8	7.7	0.96
4-4-34	24	46.5	1.94	7	12.1	1.73	9	18.7	2.08	3	6.0	2.00
4-4-35				38	61.5	1.62						
Minota				40	83.4	2.09						
4-4-36	23	44.3	1.93	8	14.3	1.79	6	7.8	1.30	1	2.4	2.40
4-4-37				28	45.6	1.63				7	7.1	1.01
4-4-38										39	47.5	1.22
4-4-39	26	49.8	1.92	5	9.6	1.92	11	15.5	1.41	1	2.3	2.30
4-4-40	28	51.2†	1.83									
Minota				36	67.7	1.88						
4-4-41	28	57.6	2.06	5	9.8	1.96	9	13.0	1.44	1	2.1	2.10
4-4-42	21	36.2†	1.72				7	13.5†	1.93			
4-4-43	Eliminated											
4-4-44	Eliminated											
4-4-45	Eliminated											
Minota				39	51.3	1.32						
4-4-46	31	36.8	1.19	4	2.6	0.65						
4-4-47				26	41.0	1.58				11	19.1	1.74
4-4-48	23	57.5	2.50	3	6.2	2.07	4	6.5	1.63	4	3.8	0.95
4-4-49				36	44.9	1.25				7	8.5	1.21
4-4-50	25	48.8†	1.95									
Minota				40	63.0	1.58						
White Russian							41	81.3	1.98			
4-4-51	28	51.5	1.84	9	15.4	1.71						
4-4-52							25	33.2	1.33	12	12.3	1.03
4-4-53	29	63.8	2.20	7	8.1	1.16						
4-4-54	26	36.8	1.42	15	18.8	1.25						
4-4-55										41	64.8	1.58
Minota				38	57.5	1.51						
4-4-56				29	37.0	1.28				9	8.6	0.96
4-4-57	22	27.4	1.25	12	8.0	0.67	6	8.2	1.37	4	5.9	1.48
4-4-58							21	30.5	1.45	8	10.8	1.35
4-4-59	33	64.2	1.95	8	10.2	1.28						
4-4-60										42	58.2	1.39

*Injured. †Corrected yield (See Table XX).

TABLE XXXV—*Continued*

PLANTING PLAN AND YIELDS OBTAINED IN THAT PART OF THE NURSERY USED TO GROW THE PARENTS AND THE MINOTA-WHITE RUSSIAN F_4 FAMILIES IN 1921. PARENTS AND PROGENY ARRANGED IN THE ORDER IN WHICH THEY APPEARED IN THE NURSERY

Culture number or parent	Open panicles						Side panicles					
	Resistant			Susceptible			Resistant			Susceptible		
	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield
		grams	grams		grams	grams		grams	grams		grams	grams
Minota				35	38.3	1.09						
4-4-61				27	39.1	1.45				7	11.1	1.59
4-4-62	20	38.5†	1.93				7	9.2†	1.31			
4-4-63	Eliminated											
4-4-64	Eliminated											
4-4-65							31	63.6	2.05	11	16.2	1.47
Minota				42	54.8	1.30						
4-4-66										40	53.5	1.34
4-4-67	29	70.5†	2.43				10	20.1†	2.01			
4-4-68	17	39.0	2.29	4	7.4	1.85	6	15.5	2.58	3	8.3	2.77
4-4-69	29	79.4	2.74				10	19.7	1.97			
4-4-70	23	40.0	1.74	9	14.1	1.57	6	13.0	2.17	3	3.7	1.23
Minota				40	59.2	1.48						
4-4-71	29	50.8	1.75	4	6.4	1.60	6	9.5	1.58	2	5.0	2.50
4-4-72				27	36.7	1.36				8	13.9	1.74
4-4-73	Eliminated											
4-4-74	20	45.0	2.25	6	8.0	1.33	10	27.8	2.78	2	1.6	0.80
4-4-75	25	78.9†	3.16				10	31.7†	3.17			
Minota				41	79.1	1.93						
4-4-76							27	61.8	2.29	13	29.6	2.28
4-4-77	26	62.1	2.39	8	16.5	2.06	5	3.8	0.76	2	2.9	1.45
4-4-78	35	76.3†	2.18									
4-4-79							38	73.9†	1.94			
4-4-80							29	43.4	1.50	11	16.2	1.47
Minota				35	55.2	1.58						
4-4-81	28	52.8†	1.89				7	10.8†	1.54			
4-4-82	24	40.1†	1.67				11	18.7†	1.70			
4-4-83	37	64.6	1.75									
4-4-84										35	34.3	0.98
4-4-85	25	21.6	0.86	10	7.5	0.75						
Minota				26	38.0	1.46						
4-4-86	31	61.5†	1.98									
4-4-87	31	87.9†	2.84									
4-4-88	26	50.4	1.94	5	9.1	1.82	9	17.8	1.98	3	7.0	2.33
4-4-89							29	60.0	2.07	10	15.0	1.50
4-4-90				39	55.0	1.41						

*Injured. †Corrected yield (See Table XX).

TABLE XXXV—*Continued*

PLANTING PLAN AND YIELDS OBTAINED IN THAT PART OF THE NURSERY USED TO GROW THE PARENTS AND THE MINOTA-WHITE RUSSIAN F_3 FAMILIES IN 1921. PARENTS AND PROGENY ARRANGED IN THE ORDER IN WHICH THEY APPEARED IN THE NURSERY

Culture number or parent	Open panicles						Side panicles					
	Resistant			Susceptible			Resistant			Susceptible		
	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield
		grams	grams		grams	grams		grams	grams		grams	grams
Minota				39	66.3	1.70						
4-4-91	18	45.2	2.51	6	7.6	1.27	5	10.2	2.04	5	9.5	1.90
4-4-92			*				37	43.6†	1.18			
4-4-93				38	47.3	1.24						
4-4-94							20	50.8	2.54	5	6.3	1.26
4-4-95	27	58.3†	2.16				12	32.7†	2.73			
Minota				38	77.8	2.05						
4-4-96	30	62.6	2.09	6	11.3	1.88	2	2.7	1.35	3	4.0	1.33
4-4-97	26	69.2	2.66	7	13.4	1.91	8	14.1	1.76	1	1.8	1.80
4-4-98				32	56.1	1.75				10	17.2	1.72
4-4-99	32	63.9†	2.00									
4-4-100							29	57.8	1.99	8	12.8	1.60
Minota				39	83.5	2.14						
White Russian							41	92.1	2.25			

*Injured. †Corrected yield (See Table XX).

TABLE XXXVI

PLANTING, PLAN AND YIELDS OBTAINED IN THAT PART OF THE NURSERY USED TO GROW THE PARENTS AND THE VICTORY-WHITE RUSSIAN F_3 FAMILIES IN 1921. PARENTS AND PROGENY ARRANGED IN THE ORDER IN WHICH THEY APPEARED IN THE NURSERY

Culture number or parent	Open panicles						Side panicles					
	Resistant			Susceptible			Resistant			Susceptible		
	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield
		grams	grams		grams	grams		grams	grams		grams	grams
White Russian							41	92.1	2.25			
Victory				31	37.6	1.21						
3-1-1	29	110.8*	3.82									
3-1-2				39	44.7	1.15						
3-1-3	5	4.2	0.84	7	7.6	1.09	6	8.3	1.38	6	5.0	0.83
3-1-4							36	100.8*	2.80			
3-1-5							23	50.3	2.19	6	6.5	1.08
Victory				26	24.3	0.93						
3-1-6				28	25.0	0.89				5	4.5	0.90
3-1-7				20	12.4	0.62						
3-1-8	25	45.1	1.80	7	6.0	0.86						
3-1-9										42	51.7	1.23
3-1-10	25	62.6*	2.50				6	14.6*	2.43			
Victory				31	24.5	0.79						
3-1-11	19	33.2	1.75	5	8.0	1.60	9	14.3	1.59	3	6.0	2.00
3-1-12				23	36.5	1.59				12	24.2	2.02
3-1-13	23	60.2	2.62	7	11.3	1.61	5	7.5	1.50	5	10.1	2.02
3-1-14	25	45.1	1.80	6	8.5	1.42	4	9.5	2.38	2	2.0	1.00
3-1-15	24	39.0*	1.63				6	11.4*	1.90			
Victory				31	28.6	0.92						
3-1-16										37	40.6	1.10
3-1-17	21	48.0*	2.29				6	13.6*	2.27			
3-1-18	16	21.8	1.36	3	1.8	0.60	5	8.0	1.60	3	2.0	0.67
3-1-19	19	45.2*	2.38				8	10.8*	1.35			
3-1-20				23	28.5	1.24				8	6.5	0.81
Victory				25	21.3	0.85						
3-1-21	26	48.6	1.87	6	6.8	1.13						
3-1-22	27	53.3	1.97	5	6.2	1.24	6	10.4	1.73	2	3.2	1.60
3-1-23	19	30.0	1.58	15	15.9	1.06						
3-1-24				36	26.1	0.73						
3-1-25				15	18.3	1.22				8	16.8	2.10
Victory				37	60.5	1.64						
3-1-26				36	55.2	1.53						
3-1-27	19	36.8	1.94	5	7.5	1.50	2	5.3	2.65	2	1.8	0.90
3-1-28	16	32.8	2.05	10	15.7	1.57	3	5.6	1.87	4	5.5	1.38
3-1-29				19	26.8	1.41				12	18.1	1.51
3-1-30							27	68.5	2.54	7	11.8	1.69

*Corrected yields (see Table XX).

TABLE XXXVI—(*Continued*)

PLANTING PLAN AND YIELDS OBTAINED IN THAT PART OF THE NURSERY USED TO GROW THE PARENTS AND THE VICTORY-WHITE RUSSIAN F_3 FAMILIES IN 1921. PARENTS AND PROGENY ARRANGED IN THE ORDER IN WHICH THEY APPEARED IN THE NURSERY

Culture number or parent	Open panicles						Side panicles					
	Resistant			Susceptible			Resistant			Susceptible		
	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield
		grams	grams		grams	grams		grams	grams		grams	grams
Victory				44	50.2	1.14						
3-1-31	22	61.6	2.80	6	7.1	1.18	4	12.8	3.20	3	4.5	1.50
3-1-32				41	80.3	1.96						
3-1-33	15	28.6	1.91	17	13.2	0.78						
3-1-34				31	60.0	1.94				7	14.1	2.01
3-1-35				36	41.2	1.14						
Victory				28	32.4	1.16						
3-1-36				34	49.1	1.44						
3-1-37	31	77.0	2.48	7	9.5	1.36						
3-1-38	30	64.3	2.14	3	4.1	1.37	4	10.5	2.63	3	1.7	0.57
3-1-39				21	33.1	1.58				13	21.2	1.63
3-1-40	21	49.1	2.34	8	9.3	1.16	3	7.1	2.37	3	6.3	2.10
Victory				40	29.5	0.74						
3-1-41	19	42.7	2.25	6	8.3	1.38	6	10.2	1.70	1	1.8	1.80
3-1-42	28	77.0*	2.75				2	6.0*	3.00			
3-1-43	22	43.6	1.98	7	9.0	1.29	5	14.4	2.88	1	1.5	1.50
3-1-44	24	49.6	2.07	4	7.8	1.95	6	12.1	2.02	2	3.7	1.85
3-1-45	14	30.9*	2.21				15	21.4*	1.43			
Victory				29	36.6	1.26						
3-1-46	31	81.6*	2.63									
3-1-47							29	63.1	2.18	11	20.9	1.90
3-1-48	12	29.8	2.48	2	6.5	3.25	4	7.8	1.95	3	7.4	2.47
3-1-49	29	84.3*	2.91									
3-1-50				27	33.5	1.24				5	6.3	1.26
Victory				29	26.5	0.91						
White Russian							34	80.7	2.37			
2-2-1	8	20.2	2.53	16	38.8	2.43	3	4.3	1.43	6	15.0	2.50
2-2-2	22	54.5	2.48	4	5.7	1.43	5	9.1	1.82	1	2.3	2.30
2-2-3	26	56.8	2.18	6	11.3	1.88	4	7.8	1.95	3	3.7	1.23
2-2-4	32	95.9*	3.00									
2-2-5	25	70.0	2.80	7	15.4	2.20	6	15.1	2.52	3	3.0	1.00
Victory				36	38.1	1.06						
2-2-6	27	64.3	2.38	10	7.7	0.77						
2-2-7	20	25.5*	1.28				7	8.9*	1.27			
2-2-8	29	93.0*	3.21				5	10.0*	2.00			
2-2-9	25	59.8	2.39	10	26.8	2.68						
2-2-10										24	32.5	1.35

*Corrected yields (see Table XX).

TABLE XXXVI—(*Continued*)

PLANTING PLAN AND YIELDS OBTAINED IN THAT PART OF THE NURSERY USED TO GROW THE PARENTS AND THE VICTORY-WHITE RUSSIAN F_2 FAMILIES IN 1921. PARENTS AND PROGENY ARRANGED IN THE ORDER IN WHICH THEY APPEARED IN THE NURSERY

Culture number or parent	Open panicles						Side panicles					
	Resistant			Susceptible			Resistant			Susceptible		
	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield
		grams	grams		grams	grams		grams	grams		grams	grams
Victory				37	42.3	1.14						
2-2-11	25	57.8	2.31	5	8.0	1.60	8	19.1	2.39	2	1.3	0.65
2-2-12				26	30.5	1.17				8	9.1	1.14
2-2-13							26	45.5*	1.75			
2-2-14	3	3.5	1.17	26	17.1	0.66	2	3.2	1.60			
2-2-15							24	57.8	2.41	7	8.7	1.24
Victory				30	23.4	0.78						
2-2-16				20	23.2	1.16				4	2.3	0.58
2-2-17										36	27.7	0.77
2-2-18										41	56.7	1.38
2-2-19	22	45.3	2.06	9	10.1	1.12	2	3.3	1.65	4	4.5	1.13
2-2-20							23	34.6	1.50	9	7.8	0.87
Victory				40	50.8	1.27						
2-2-21	22	50.0	2.27	7	9.2	1.31	5	9.5	1.90	4	2.5	0.63
2-2-22	23	52.8	2.30	7	15.3	2.19	5	6.5	1.30	4	3.6	0.90
2-2-23	27	46.2	1.71	6	2.0	0.33	4	9.7	2.43	2	2.3	1.15
2-2-24	23	35.3	1.53	6	5.7	0.95						
2-2-25	20	37.4*	1.87				5	6.2*	1.24			
Victory				33	27.6	0.84						
2-2-26	21	26.6	1.27	10	4.8	0.48						
2-2-27				26	41.1	1.58				6	7.8	1.30
2-2-28							30	46.3	1.54	6	5.3	0.88
2-2-29										41	44.4	1.08
2-2-30										36	46.3	1.29
Victory				44	36.8	0.84						
2-2-31	20	34.8	1.74	11	12.9	1.17	2	2.5	1.25	4	7.8	1.95
2-2-32	24	41.7*	1.74				5	10.0*	2.00			
2-2-33				33	32.5	0.98						
2-2-34							29	44.7*	1.54			
2-2-35	29	52.8*	1.82									
Victory				31	26.8	0.86						
2-2-36	20	29.5	1.48	6	7.1	1.18	6	17.4	2.90	3	3.6	1.20
2-2-37	18	27.1*	1.51									
2-2-38	19	32.6	1.72	6	10.1	1.68	10	16.0	1.60	2	1.8	0.90
2-2-39	21	31.0	1.48	5	8.2	1.64	3	3.5	1.17	4	2.0	0.50
2-2-40	21	33.5	1.60				6	8.6	1.43			

*Corrected yields (see Table XX).

TABLE XXXVI—(*Continued*)

PLANTING PLAN AND YIELDS OBTAINED IN THAT PART OF THE NURSERY USED TO GROW THE PARENTS AND THE VICTORY-WHITE RUSSIAN F_3 FAMILIES IN 1921. PARENTS AND PROGENY ARRANGED IN THE ORDER IN WHICH THEY APPEARED IN THE NURSERY

Culture number or parent	Open panicles						Side panicles					
	Resistant			Susceptible			Resistant			Susceptible		
	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield	No. of plants	Total yield	Average yield
		grams	grams		grams	grams		grams	grams		grams	grams
Victory				37	44.8	1.21						
2-2-41	18	44.1	2.45	5	3.4	0.68	5	15.1	3.02	2	1.5	0.75
2-2-42	11	33.6	3.05	16	37.6	2.35	2	2.8	1.40	10	20.3	2.03
2-2-43				7	10.6	1.51				4	8.4	2.10
2-2-44	15	32.4	2.16	9	14.3	1.59	2	2.8	1.40	2	3.0	1.50
2-2-45	20	41.3	2.07	7	12.1	1.73						
Victory				36	39.1	1.09						
2-2-46	19	37.2	1.96	6	5.5	0.92	10	13.8	1.38			
2-2-47	21	39.1	1.86	5	5.5	1.10	4	11.3	2.83	1	2.0	2.00
2-2-48	Eliminated											
2-2-49	17	42.5	2.50	6	6.3	1.05	9	19.8	2.20	4	6.5	1.63
2-2-50										39	49.3	1.26
Victory				34	38.0	1.12						
White Russian							36	71.1	1.98			

*Corrected yields (see Table XX).

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